Echinoids from the Triassic (St. Cassian) of Italy, Their Lantern Supports, and a Revised Phylogeny of Triassic Echinoids

PORTER M. KIER

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ABSTRACT

Kier, Porter M. Echinoids from the Triassic (St. Cassian) of Italy, Their Lantern Supports, and a Revised Phylogeny of Triassic Echinoids. *Smithsonian Contributions to Paleobiology*, number 56, 41 pages, 4 figures, 14 plates, 1984.—Three new species of Triassic echinoids are described from the St. Cassian (Karnian) beds of Cortina d'Ampezzo, Italy: *Levicidaris furlani, L. pfaifferi,* and *Zardinechinus giulinii*. Hundreds of echinoid fragments from the same beds show that 16 species lack apophyses (interambulacral lantern supports) and 7 possess them. Previously, paleontologists assumed that most Triassic echinoids had apophyses. Their absence from so many species and the presence of slightly developed auricles (ambulacral lantern supports) suggest that two echinoid lineages crossed from the Paleozoic to the Triassic: one, possessing apophyses, is ancestral to all modern cidaroids; a second, lacking apophyses, gave rise to all noncidaroid echinoids.

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Echinoids from the Triassic (St. Cassian) of Italy, Their Lantern Supports, and a Revised Phylogeny of Triassic Echinoids

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Introduction

The best preserved Triassic echinoids come from the St. Cassian beds (Karnian) near Cortina D'Ampezzo, Italy. A large collection of these echinoids was described recently (Kier, 1977), but additional material has been found that includes 3 new species and also fragments that show the nature of lantern supports in many of the species. Previously, it was believed that most Triassic echinoids had lantern supports formed from interambulacral plates (apophyses); however, the majority of St. Cassian echinoid specimens studied have no apophyses and either had no lantern supports or have supports formed from ambulacral plates (auricles). This new information requires revision of our understanding of the phylogeny and the higher taxonomic categories of Triassic echinoids.

ACKNOWLEDGMENTS.—I thank Rinaldo Zardini of Cortina d'Ampezzo who permitted me to study all his St. Cassian fragments, including newly collected material. All the specimens figured in this paper in the section on lantern supports were collected by him.

Giovanni Furlan of Treviso, Italy, arranged the loan of a large number of St. Cassian echinoids collected by himself, Fabrizio Bizzarini, Eugenio Pfaiffer of Venice, and Saverio Giulini of Milan. I thank them for having the patience and skill necessary to find these rare fossils and for their willingness to lend them to me for study. These specimens are described in the "Species Discussion" section, including the type specimens of the three new species.

David Pawson and Gordon Hendler of the Smithsonian Institution critically read the manuscript, and Andrew Smith of the British Museum (Natural History) shared his cladistic approach with me and showed me how to use it to better understand the phylogeny of Triassic echinoids.

Most of the photography was done by Arnold L. Powell and the artwork by Larry B. Isham. The manuscript was edited by Donald C. Fisher, Smithsonian Institution Press, and I thank him for his suggestions.

LOCALITIES.—All the echinoids were collected

Porter M. Kier, Department of Paleobiology, National Museum of Natural History, Smithsonian Institution, Washington, D.C. 20560.

from the following localities in the Dolomites region of Italy.

Alpe di Species: SW of base of Monte Specie, approximately 12 km NE of Cortina d'Ampezzo.
Boa Staolin: 1 km NE of Alvera, approximately 2.5 km NE of Cortina d'Ampezzo.
Campo: approximately 2.01 km S of Cortina d'Ampezzo.
Cianzope: 2.5 km E of Lago Bai di Dones, approximately 5.5 km W of Cortina d'Ampezzo.
Forcella Giau: 2.5 km NE of Selva di Cadore, approximately 9 km SW of Cortina d'Ampezzo.
Milires: 0.5 km W of Campo di Sotto, a town 2.25 km S of Cortina d'Ampezzo.
Misurina: 2 km E of base of Mt. Cristallino, 10.5 km NE of Cortina d'Ampezzo.
Rumerlo: 0.25–0.5 km S of Rumerlo, town 2.5 km W of Cortina d'Ampezzo.
Stolla: 2.5 km NW of Monte Specie.
Tamarin: 300 m NE of Lake Tamarin, approximately 3 km NE of Cortina d'Ampezzo.
St. Cassiano: Badia Valley, near Rio Stuores.

The specimens are deposited in the Museo di Cortina d'Ampezzo, Cortina d'Ampezzo, Italy (MCA); the Museo di Storia Naturale, Venice, Italy (MV); the National Museum of Natural History, Smithsonian Institution, Washington, D.C. (USNM); and in the Pfaiffer (private) collection in Venice, Italy.

Lantern Supports

The lantern of an echinoid is attached by two sets of muscles to the test near the inside edge of the peristomial opening. One set of muscles, the retractors, serve to pull the lantern back and the second set, the protractors, extend the lantern. The retractors in all modern cidaroids are attached to projections, called apophyses, at the edge of the interambulacra. In all noncidaroid, regular echinoids no apophyses are present, and the retractors are attached to projections, called auricles, in the ambulacra. The protractors are attached always to the interambulacra. In the cidaroid, these muscles attach to the medial region in the apophyses; in the noncidaroids they are attached to a slight ridge along the peristomial edge of the interambulacra.

Lantern supports are absent in lower Paleozoic echinoids. They first appear in the Permian where apophyses (interambulacral supports) are present (Kier, 1974:56) in *Miocidaris keyserlingi* (Geinitz) and *Miocidaris connorsi* Kier. Apophyses are present in the Early Triassic *Lenticidaris utahensis* Kier. It has been assumed that the vast majority of Triassic echinoids were cidaroids having apophyses; however, study of these St. Cassian fragments shows that most of the species had no apophyses and that some of those lacking apophyses had slightly developed lantern supports in their ambulacra (auricles). They include the following 16 species:

Zardinechinus lancedelli (Zardini)
Z. giulinii, new species
Levicidaris zardinia Kier
L. furlani, new species
L. pfaifferi, new species
Megaporocidaris mariana Kier
Tiarechinus princeps Neumayr
Triadocidaris venusta (Münster)
Paurocidaris rinbianchi (Zardini)
"Miocidaris" adrianae Zardini
Mikrocidaris pentagona (Münster)
5 unnamed species

The auricles, when present, are commonly formed by thickening of the first three plates at the adoral edge of each ambulacrum (Figure 1; Plate 1: figures 1–3). Although the edges of the adjacent interambulacra are thickened, they are not part of the auricle, which lies on top of the interambulacra. In many of these species a small protuberance is present in the middle of the inside of the interambulacra. The protractor muscles were presumably attached here. In modern echinoids the protractor muscles are always attached medially in each interambulacrum relative to the retractor muscles.

Apophyses are present in the following St. Cassian species:

Polycidaris regularis (Münster)
"Miocidaris" ampezzana Zardini
Leurocidaris montanaro (Zardini)
4 unnamed species

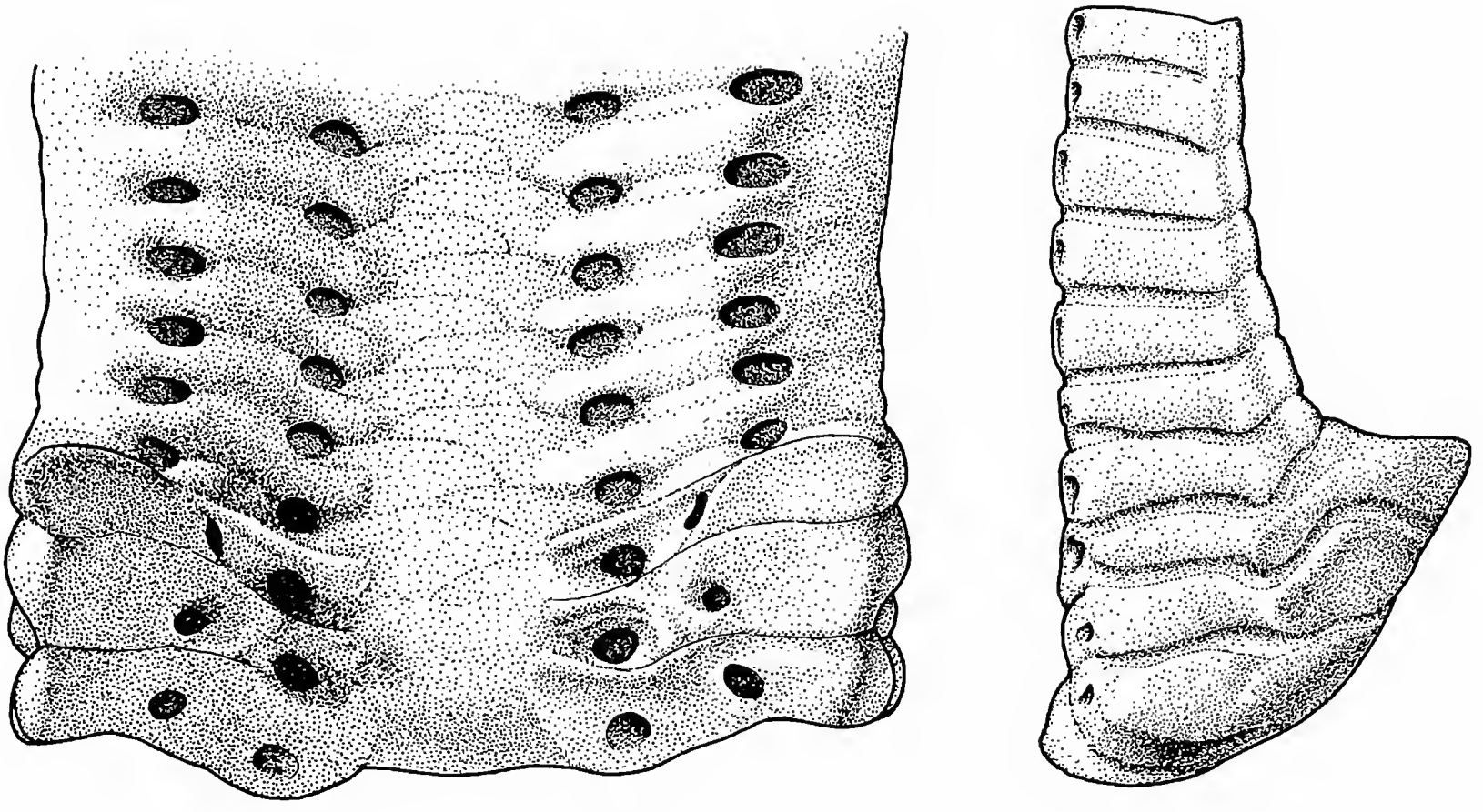


FIGURE 1.—Interior and adradial views of adoral margin of an ambulacrum, MCA 5689, showing the auricles, × 20. Campo. Collector: Zardini.

DISCUSSION

The sixteen species lacking apophyses cannot be considered to be cidaroids. It is unreasonable to suggest that cidaroids gained apophyses in the Permian and lost them in the Triassic and then later regained them. If they had, it would be expected that there would be intermediate forms—species with vestigial apophyses and small auricles—but none have been found. The late Triassic echinoids with small auricles have no traces of apophyses.

It is more reasonable to assume that two echinoid lineages (Figure 2) crossed from the Permian to the Triassic. One, the cidaroids, had apophyses and the other, an unnamed supratax a, had no lantern supports. This latter lineage developed auricles in the Late Triassic and is ancestoral to all living, noncidaroid echinoids. Regular echinoids lacking lantern supports became extinct at the end of the Triassic.

Nature of Lantern Supports in St. Cassian Species

SPECIES WITHOUT APOPHYSES

Zardinechinus lancedelli (Zardini)

PLATE 1: FIGURES 4, 5

The lantern supports in this species consist of auricles formed by thickening of the three adoral-most ambulacral plates in each column. The highest part of each auricle rises from the third plate, forming a tab to which, presumably, were attached retractor muscles of the lantern. Although the interambulacra thicken at the adradial margin, the retractors presumably were not attached to the interambulacrum. The ambulacral auricles (as viewed from the interior) rest on top of the adradial margin of the interambulacra. No protuberance is present at the adoral margin in the middle of each interambu-

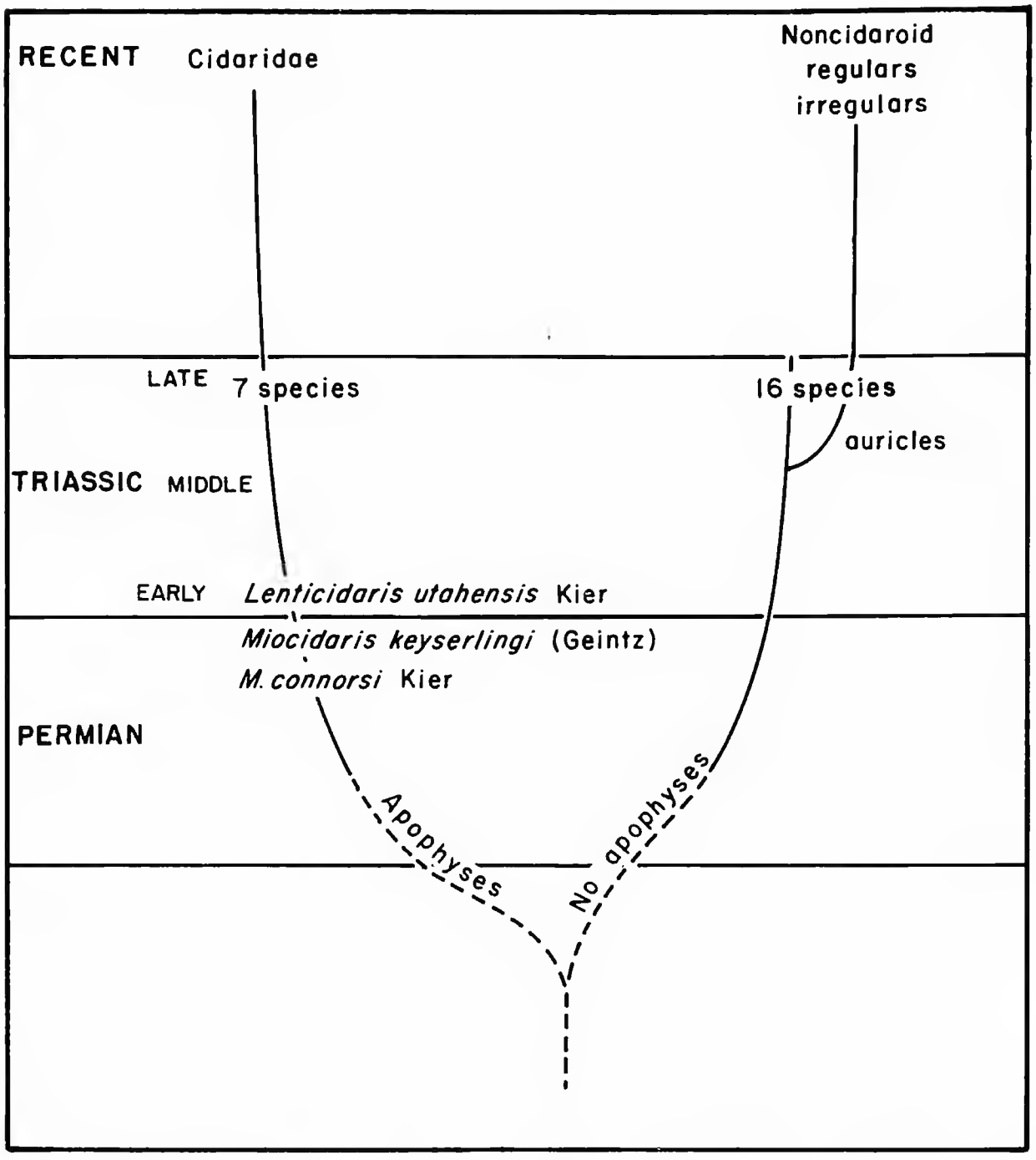


FIGURE 2.—Phylogeny of the echinoids based on character of lantern supports.

lacrum. More than one hundred interambulacra of this species were examined and none of them had this protuberance. (See "Species Discussion.")

Zardinechinus giulinii, new species

The interior at the edge of the peristome is visible in the holotype and one of the paratypes. No apophyses are present. The ambulacra are thickened at the adradial suture, forming an auricle similar to that in *Zardinechinus lancedelli.* (See "Species Discussion.")

Levicidaris zardinia Kier

PLATE 1: FIGURES 6, 7

The lantern supports in this species are indistinguishable from those in *Z. lancedelli;* they are clearly visible in USNM 370501. There are no apophyses. The ambulacra and interambulacra

are thickened at the adradial margin. The three adoral-most plates in each ambulacral column are thickened, forming an auricle. The highest part of the auricle rises from the third plate. (See "Species Discussion.")

Levicidaris furlani, new species

The lantern supports are similar to those in *L. zardinia*. No apophyses are present. Slight auricles are formed by thickening of the adoral-most plate in each ambulacral column. (See "Species Discussion.")

Levicidaris pfaifferi, new species

The lantern supports are similar to those in *L. zardinia*. There are no apophyses. Slight auricles are formed by the thickening of the adoral-most ambulacral plates. (See "Species Discussion.")

Megaporocidaris mariana Kier

Several fragments, MCA 3146-S-Z and 3147-S-Z (Kier, 1977, pl. 15: figs. 6, 8), show the interior adoral edge of the test. No apophyses are present. Although thickening occurs at the edge of the adoral-most ambulacral plates, it is not clear whether or not auricles are present. (See "Species Discussion.")

Paurocidaris rinbianchi (Zardini)

No apophyses are visible on the holotype, MCA 125-M-Z.

Tiarechinus princeps Neumayr

On specimen MCA 193-S-Z no apophyses are present. The plates at the peristomial edge of the ambulacra are thickened, forming slight auricles. (See "Species Discussion.")

Triadocidaris venusta (Münster)

The peristomial region is preserved on the holotype (AS VII 436) in the Bayerische Staatssammlung für Pälaontologie und Historische Geologie, Munich, West Germany. No apophyses are present. Although the ambulacra are thickened at the adradial suture, no auricles are preserved.

Species 1

PLATE 2: FIGURES 1–6

MATERIAL.—MCA 5692, 5693, 5694.

Although the species cannot be generally identified, it is distinguished from the other St. Cassian species by its wide interambulacra with perforate tubercles adorally. Its tubercles have parapets which are not crenulate except for two crenulations on the adoral side of each tubercle.

This species differs from species 2 by its larger size and much narrower medial tract.

All 15 fragments show the inside of the adoral edge of interambulacra. No apophyses are present. The interambulacra are thickened at the adradial suture. A protuberance is present in the middle of the interior of the adoral edge on most of the specimens (Plate 2: figure 4). This protuberance probably was the point of attachment of the protractor muscles. No specimens of this species have been found with ambulacra, so it is not known whether or not auricles were present.

Species 2

PLATE 3: FIGURES 1–6; PLATE 4: FIGURES 1, 2

Triadocidaris species B.—Kier, 1977:25, pl. 18: figs. 3–5.

MATERIAL.—MCA 168, 192, 5696, 5698.

Ninety-three fragments can be referred to this species, which is easily distinguished from the other St. Cassian species by its small, wide test, perforate tubercles, and wide medial tract.

This species has no apophyses. The interambulacra are thickened at the adradial suture, and on most specimens a protuberance is present in the middle of the inside adoral edge of each interambulacrum. No specimens are available with ambulacra; therefore, it is not known whether this species had auricles.

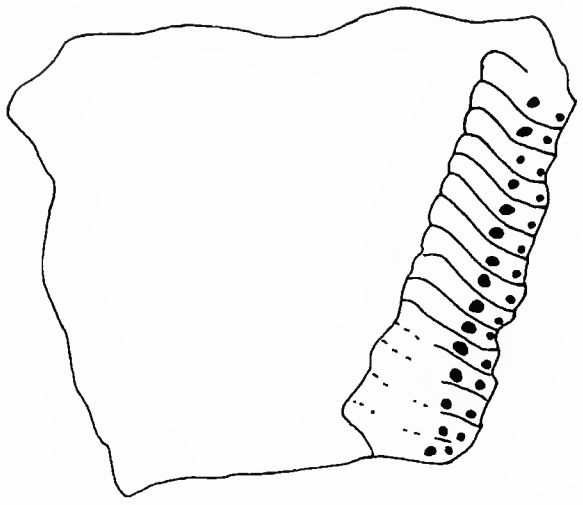


FIGURE 3.—Species 3 showing sutures, MCA 5699, × 20. Campo. Collector: Zardini.

Species 3

FIGURE 3; PLATE 4: FIGURES 3, 4

MATERIAL.—MCA 5699.

This species is based on only one fragment including the adoral portion of a half interambulacrum and ambulacrum. It is easily distinguished from all the other St. Cassian species by the many columns of tubercles in the interambulacra. At the adradial suture both the interambulacrum and ambulacrum are thickened, forming a ridge that was probably an auricle. This is the only specimen I have seen on a Triassic echinoid in which the auricle is partially interambulacral in origin. A large protuberance is present at the midline of the interambulacrum.

"Miocidaris" adrianae Zardini

PLATE 4: FIGURES 5, 6; PLATE 5: FIGURES 1–6

Miocidaris adrianae Zardini, 1973:9, pl. 6: fig. 25.
Species 1.—Kier, 1977:26, pl. 18: figs. 6–8, pl. 19: figs. 1, 2.

MATERIAL.—*Holotype:* MCA 121.
Paratypes: MCA 5700, 5701, 5702.

This species is based on three specimens besides Zardini's holotype. Although I cannot generically identify it, it is easily distinguished from the other St. Cassian species by its strongly crenulate, perforate tubercles and deep pits on the interior of the interambulacra behind the primary tubercles. Nothing is known of the ambulacra. No apophyses are present. The interambulacra are only very slightly thicker at the adradial margin. A slight protuberance occurs adorally at the midline (Plate 5: figure 2).

Species 4

Species 2.—Kier 1977:26, pl. 19: fig. 3.

This species is based on only one fragment (MCA 3154-R-Z) of an interambulacrum and cannot be identified generically. It differs from *"Miocidaris" adrianae* in having lower plates and more strongly elevated bosses lacking basal terraces. It lacks an apophysis.

Species 5

PLATE 6: FIGURES 1, 2

Mesodiadema?.—Kier, 1977, pl. 19: figs. 4, 5 [fragments].

MATERIAL.—MCA 5704.

Three interambulacral fragments are known of this species, which is easily distinguished from the other St. Cassian species by its more numerous interambulacral tubercles. No apophyses are present. The adradial margins of the interambulacra are thickened, and a protuberance is well developed medially near the adoral edge.

Mikrocidaris pentagona (Münster)

No apophyses are visible on any of the specimens I have seen of this species. (See "Species Discussion.")

SPECIES WITH APOPHYSES

Polycidaris regularis (Münster)

The holotype, AS VII 435, is the only known specimen of this species and is in the Bayerische Staatssammlung für Pälaontologie und Historische Geologie, Munich, West Germany. The

apophyses are low and inclined (Kier, 1977:16). No auricles are present.

Species 6

PLATE 6: FIGURES 3, 4

Mesodiadema?.—Kier, 1977:27, pl. 19: figs. 6–9 [fragment].

MATERIAL.—MCA 3156-S-Z, 5705.

This species is easily distinguished by its small, eccentrically situated primary tubercles and very small and numerous secondary tubercles. Two specimens are known; both are only adoral portions of an interambulacrum. Specimen MCA 3156-S-Z was illustrated by Kier (1977, pl. 19: figs. 6, 7). Its apophysis is bilobed, very large, occupying most of the adoral border of the interambulacrum. The other specimen, MCA 5705 (Plate 6: figures 3, 4), has the apophysis only partially preserved. It is massive, bilobed, and is formed by the thickening of the first three plates in each column of the interambulacrum, with most of the apophysis formed by the second plate in each column. There is no thickening of the interambulacrum at the adradial margin.

Species 7

PLATE 6: FIGURES 5, 6

Mesodiadema?.—Kier, 1977:27, pl. 20: figs. 1, 2 [fragment].

MATERIAL.—MCA 3159-S-Z, 5706.

This species is represented by two specimens. The species resembles species 6 but differs in having higher plates. In specimen MCA 3159-S-Z, illustrated in Kier (1977, pl. 20: figs. 1, 2), the apophysis is massive, occupying all the adoral border between the adradial margin. It is bilobed with a narrow indented section medially. The adradial margin thickens only very slightly adorally. Each apophysis is formed by the thickening of the first three interambulacral plates of each column with most of the apophysis formed from the second plate. The adradial margin thickens slightly adorally.

"Miocidaris" ampezzana Zardini

PLATE 7: FIGURES 1, 2

Miocidaris ampezzana Zardini, 1973:9, pl. 6: fig. 23.

MATERIAL.—*Holotype:* MCA 119.
Paratype: MCA 120.

This species cannot be generically identified. It resembles most specimens of species 5 in its small secondary tuberculation but differs in having far larger primary tubercles. Both the holotype and figured paratype show part of the lantern supports. The apophyses are large, including the full width of the adoral edge of each interambulacrum. They are bilobed and formed from the first three plates of each interambulacrum and are mostly formed from the second plate in each column. The adradial margin is not thickened adorally.

Species 8

PLATE 7: FIGURES 3, 4

MATERIAL.—MCA 5708.

This species cannot be generically identified. Only one fragment is known. Large crenulate tubercles and sparse secondary tuberculation distinguish this species from the other St. Cassian species. Its apophysis is bilobed and wide, extending across the full width of the interambulacrum at the adoral edge. It is formed of the first two plates in each column. Most of the apophysis is formed from the first plate in one column and the second plate in the other column.

Species 9

PLATE 7: FIGURES 5, 6

MATERIAL.—MCA 5709.

Although this species cannot be generically identified, it is easily distinguished from the other St. Cassian species that have apophyses. Its large tubercles have but few crenulations on the adoral side of each tubercle. The apophysis is bilobed, formed by the first two or three interambulacral

plates in each column. On first impression the first plate in one of the columns appears to be the main constituent, but this plate is really the second in the column—the first plate being almost completely resorbed. A thickened flange borders the upper edge of the apophysis and extends down to the adoral margin. A small protuberance occurs medially between the lobes of the apophyses.

Leurocidaris montanaro (Zardini)

Two specimens, MCA 3142-S-Z and USNM 370502, show the inside of the adoral edge of an interambulacrum. A pronounced ridge occurs along the adoral margin which may be an apophysis.

Nature of Some Ambulacra in St. Cassian Species

There are many fragments of ambulacra but most cannot be identified. Some are composed entirely of primary plates (MCA 5710, Plate 7: figure 7) but many have their plates compounded adorally. On some a tubercle occurs on every other plate (MCA 5711, Plate 7: figure 8). On some a tubercle covers a pair of plates with a single plate, lacking a tubercle, separating the pair (MCA 5712, Plate 7: figure 9). All the ambulacra have their porepairs uniserially arranged except for one specimen with its pores biserially arranged.

A Biserial Ambulacrum

(Figure 4; Plate 8: figures 1, 2)

Material.—MCA 5713.

This is the only example of biserial pores I have seen in the Triassic. The plates strongly bevel under the adjacent interambulacra as typical in many other St. Cassian species such as *Zardinechinus*. Plates are enfolded around each other. The plates bearing the outer porepairs (even numbered on Figure 4) appear to be demiplates (not touching the perradial or medial suture), but this separation occurs only on the exterior of the test. As can be seen on an edge view of the ambulacrum along the perradial suture, these plates reach the perradial suture below the surface of the test. The plates that bear the outer porepairs extend over the tops of the adjacent plates that bear the inner pores, separating these plates from the adradial sutures (externally). The perradial portions of these separated plates are more and more deeply covered by the adjacent plates adorally. This is seen in the edge view along the perradial suture where these "demiplates" (even numbered) become shorter. In the upper, or more adapical, part of the ambulacrum these plates reach the exterior of the test (as in plate number 2 on Figure 4), whereas adorally (as in plate number 16) the plates are deeply covered by the adjacent ambulacral plates, with a height less than one-half the thickness of the ambulacrum.

Likewise, the plates that bear the inner porepairs appear to be occluded (touching the perradial but not the adradial sutures). This separation occurs only on the exterior of the test—internally these plates reach the adradial suture. The plates that bear the inner porepairs (odd numbered on Figure 4) extend externally over the plates that bear the outer porepairs, isolating them externally from the perradial suture.

Presumably this intricate interlocking of the ambulacral plates would strengthen the ambulacrum and serve to resist the strain imparted by the contraction of the tubefeet when attached to the substratum or a heavy object.

Species Discussion

Mikrocidaris pentagona (Münster)

Plate 8: figures 3, 4

Cidaris pentagona Münster in Wissmann and Münster, 1841:42, pl. 3: fig. 8.—d'Orbigny, 1849:206.—Giebel, 1852:316.—Desor, 1855:4.—Laube, 1865a:280, pl. 9: fig. 3; 1865b:325.

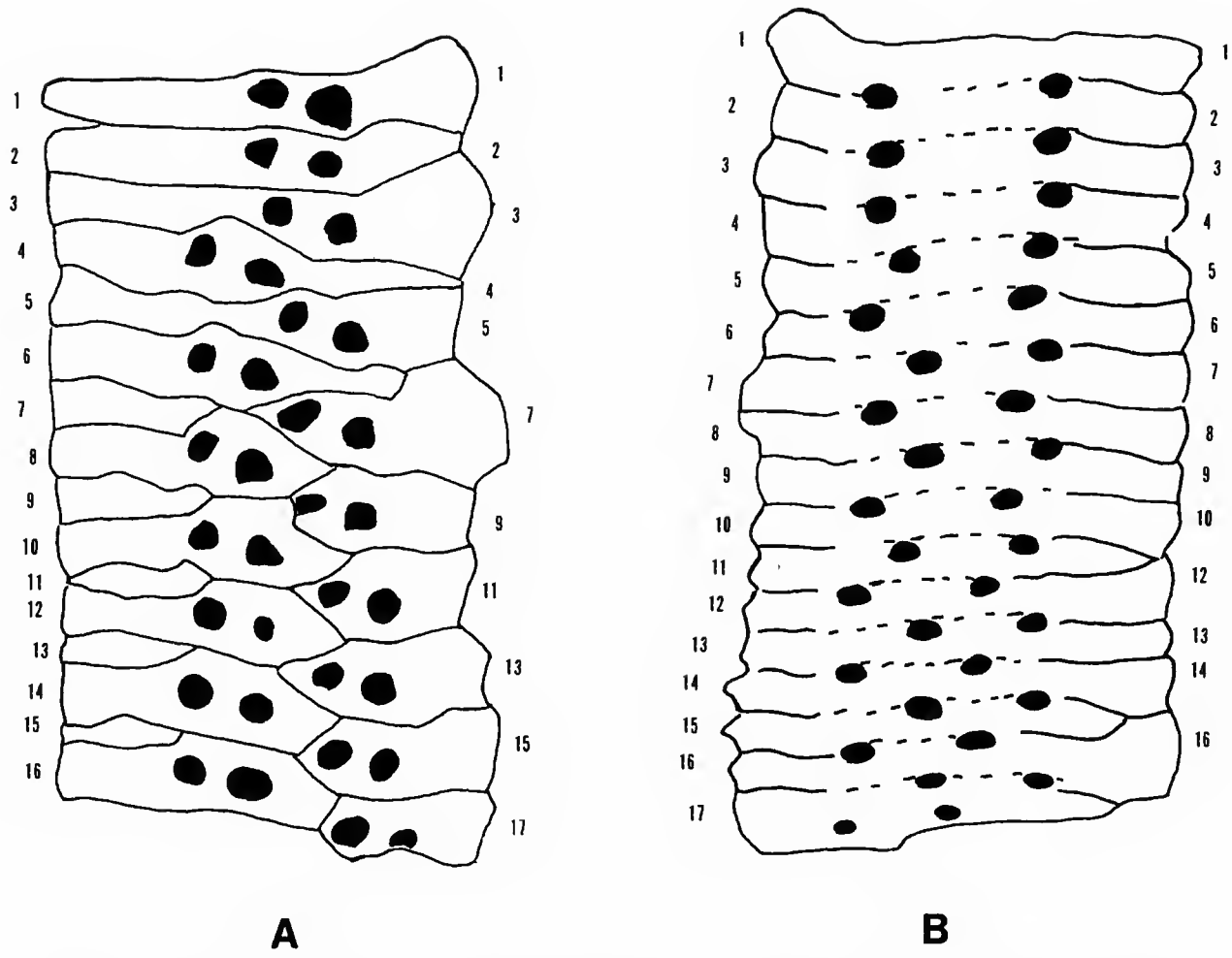


FIGURE 4.—Biserial ambulacrum, MCA 5713: A, exterior view; B, interior view; × 12. Campo. Collector: Zardini.

Microcidaris pentagona (Münster).—Döderlein, 1887:39.—Lambert and Thiéry, 1910:140.—Mortensen, 1928:64, fig. 34.—Zardini, 1973:9, pl. 5: figs. 18, 19.—Kier, 1974:17, 71, 79; 1977:13, fig. 4, pl. 2: figs. 3–6, pl. 3: figs. 1, 2, pl. 4: figs. 1, 2.

Cidaris subpentagona Braun in Wissman and Münster, 1841:42, pl. 3: fig. 9.—d'Orbigny, 1849:206.—Giebel, 1852:316.—Desor, 1855:4.—Laube, 1865a:282, pl. 9: fig. 9; 1865b:325. [Not Zardini, 1973:13, pl. 5: figs. 16, 17.]

Mikrocidaris subpentagona (Braun).—Döderlein, 1887:39.—Lambert and Thiéry, 1910:140.—Kier, 1974:17.

MATERIAL.—MV 10084.

One well-preserved specimen of this species has a diameter of 4.6 mm, height of 2.7 mm, with the diameter of the apical system 1.0 mm and the peristome 2.8 mm. An ambulacrum has 23 plates and an interambulacrum 12.

OCCURRENCE.—Milieres. Collector: Giulini.

Megaporocidaris mariana Kier

PLATE 9: FIGURES 1–5

Megaporocidaris mariana Kier, 1977:23, pl. 15: figs. 6–8, pl. 16.

MATERIAL.—MV 10085.

Five other specimens (in private collections, unnumbered) can be referred to this species. The dimensions (in mm) are given below.

Diam.	*Height*	*Ht./ diam. (%)*	*No. of interamb. plates*	*No. of amb. plates*	*Diam. of apical system*	*Diam. of peristome*
6.0	3.9	65	13	34	–	–
8.4	5.4	64	14	34	–	–
7.4	–	–	–	34	–	–
6.2	4.1	66	13	36	3.0	3.0
5.3	3.4	64	12	34	2.5	–

OCCURRENCES.—Alpe di Species, Misurina, Rumerlo. Collectors: Giulini, Furlan, Bizzarini.

Tiarechinus princeps Neumayr

Tiarechinus princeps Neumayr, 1881:169, pl. 2, fig. 4a–c.—Lovén, 1883:11, 64, pl. 13: figs. 150–162.—Mortensen, 1935:519, fig. 312a–e.—Kier, 1977:24, fig. 7, pl. 17: figs. 1–5.

Two specimens of this species are in a private, unnumbered collection. The best preserved specimen has a diameter of 3.1 mm, a height of 1.9 mm, and its periproct has a diameter of 0.6 mm. The diameter of the peristome is 1.9 mm and 22 plates are in an ambulacrum, 4 in an interambulacrum.

OCCURRENCE.—Tamarin. Collector: Giulini.

Levicidaris zardinia Kier

PLATE 1: FIGURES 6, 7

Levicidaris zardinia Kier, 1977:21, pl. 14: figs. 1–5, pl. 15: figs. 1–5.

MATERIAL.—MCA 5691, USNM 370501.

Twelve other specimens of this species are in a private, unnumbered collection. Eight of them are well enough preserved to show the dimensions (in mm) of the test.

Diam.	*Height*	*No. of amb. plates*	*No. of interamb. plates*	*Diam. of apical system*	*Diam. of peristome*
13 (est.)	7.3	60	–	–	–
14.2	8.6	74	11	7.0	–
11.5	6.9	62	11	5.5	–
8.3	4.7	56	11	–	–
13	–	66	11	5.7	–
8.2	4.1	48	10	–	–
11.4	5.6	62	11	–	5.4
14.5	8.0	–	–	–	–

OCCURRENCES.—Misurina, Alpe di Species. Collectors: Bizzarini, Furlan, Pfaiffer, Giulini.

Levicidaris furlani, new species

PLATE 10: FIGURES 1–6; PLATE 11: FIGURES 1–4

MATERIAL.—Four specimens can be referred to this species. The holotype is slightly distorted but the surface detail is well preserved.

Holotype: MV 10086.

Paratype: MCA 5715.

SHAPE AND SIZE.—The diameter varies from 6.7 to 11.4 mm, with a height from 46 to 52 (mean 48) percent of the diameter.

APICAL SYSTEM.—No plates are preserved. The diameter of the system varies from 41 to 45 percent of the diameter of the test (D).

AMBULACRA.—The ambulacra are straight. The greatest width at the margin is 13–15 percent D. The plates are all primaries (Plate 10: figure 3), each having a secondary tubercle along the perradial suture. These tubercles form a double vertical column running medially down each ambulacrum. The pores are in well-developed peripodia, with a high ridge running transversely adapical to each porepair. A ridge separates the pores of a pair. An ambulacrum in the smallest specimen, 6.7 mm in diameter, has 44 porepairs; the largest specimen, 11.4 mm in diameter, has 58 porepairs. The outer pore of each pair is situated adapically to its partner.

INTERAMBULACRA.—Each interambulacrum is composed of 10 plates in the smallest specimen to 12 plates in the largest. All the tubercles are imperforate except for the most adapical plate of the left-hand column of each interambulacrum. This tubercle is perforate. Its mamelon is smaller than on the tubercle adoral to it. The bosses of the most adapical tubercles are the largest, decreasing in size adorally. On the largest specimen, the mamelon on the most adapical plate of the right-hand column of an interambulacrum rises 0.6 mm above the parapet. A ring of scrobicular tubercles encircles each tubercle. They are partially confluent on some of the transverse sutures. The most adapical plate in the right-hand column of each interambulacrum bears no tubercle.

PERISTOME.—The peristome has a diameter equal to 44–48 percent the diameter of the test. Slight notches, perhaps gill slits, occur at the edge of the interambulacra.

LANTERN SUPPORTS.—No apophyses are present. Slight auricles are formed by thickening of the adoral-most ambulacral plates.

COMPARISON WITH OTHER SPECIES.—The

other two species of *Levicidaris*, including the type-species (*L. zardinia*), have all their tubercles imperforate, whereas the adapical most tubercle in the left-hand column of each interambulacrum in *L. furlani* is perforate. This difference broadens the definition of *Levicidaris* but in all other important characters this species is similar to *Levicidaris*.

This species further differs from *Levicidaris zardinia* and *L. pfaifferi* in having the tubercle on the most adapical plate in the left-hand column of each interambulacrum smaller than the tubercle on the plates adoral to it. Furthermore, the scrobicules are less depressed along their outer rims in *L. furlani*.

OCCURRENCES.—Stolla, Alpe di Species, Misurina. Collectors: Furlan, Giulini, Bizzarini.

Levicidaris pfaifferi, new species

PLATE 11: FIGURES 5–7; PLATE 12: FIGURE 1

MATERIAL.—The holotype is very well preserved and undistorted. It lacks its apical system and lantern.

Holotype: Pfaiffer collection (private) 164.

SHAPE AND SIZE.—The diameter of the test (D) is 11.1 mm and the height 7.6 mm or 76 percent D.

APICAL SYSTEM.—No plates are preserved. The sytem has a diameter of 5.6 mm (est.) or 50 percent D.

AMBULACRA.—The ambulacra are straight to slightly sinuate. The greatest width at the ambitus is 1.8 mm or 17 percent D. The plates are all primaries (Plate 11: figure 6), each having a secondary tubercle along the perradial suture. These tubercles form a double vertical column running medially down each ambulacra. The pores are situated in well-developed peripodia. Each ambulacrum has 64 porepairs. The peripodia are well developed with a transverse ridge running across the top of each porepair and a high ridge separating pores of a pair.

INTERAMBULACRA.—Each interambulacrum is composed of 10–11 plates. All plates bear a primary tubercle except the first adapical plate of the left-hand column (as viewed from above). None of the tubercles are perforate or crenulate. The mamelons are undercut and largest on the more dorsal plates. Their height is 0.5 mm or 4.5 percent D, and with a horizontal diameter of 1.0 mm. The bosses are well developed. A ring of approximately 15 tubercles surrounds each boss. A few of the more dorsal tubercles are confluent, with no secondary tubercles separating tubercles in the same row.

PERISTOME.—The diameter of the opening is 6 mm. Notches, presumably gill slits (Plate 12: figure 1), are present on the edges of the interambulacra.

LANTERN SUPPORTS.—Apophyses are absent. The edge of the ambulacra are thickened.

COMPARISON WITH OTHER SPECIES.—*Levicidaris pfaifferi* differs from *Levicidaris zardinia*, also from the St. Cassian beds, in having wider ambulacra, 17 percent D as opposed to 12 to 14 in *L. zardinia*. The interambulacra are narrower in *L. pfaifferi*, with only the tubercles in the scrobicular rings separating adjacent tubercles, whereas in *L. zardinia* the tubercles are separated by several rows of secondary tubercles.

OCCURRENCE.—Misurina. Collector: Pfaiffer.

Zardinechinus giulinii, new species

PLATE 12: FIGURES 2–6; PLATE 13: FIGURES 1–4

MATERIAL.—The holotype is well preserved, with the test not distorted. The apical system and lantern are absent. Two paratypes are also well preserved.

Holotype: MV 10088.

Paratypes: MV 10089 and one unnumbered specimen in a private collection.

SHAPE AND SIZE.—The test is small; the holotype has a horizontal diameter of 8.4 mm, with a height of 4.5 mm or 53 percent D. The marginal outline of the test is pentagonal with interambulacral apices. The test is flattened dorsally with the upper plates at the margin of the apical system horizontal.

APICAL SYSTEM.—All the plates of the apical system are absent. The system was large with a diameter of 45–47 percent D. The outline of the

system is pentagonal with the apices in the ambulacra.

AMBULACRA.—The ambulacra are straight and have their greatest width at the ambitus, where the width of an ambulacrum is 13–15 percent D. The plates are all primaries (Plate 12: figures 5, 6) with no change adorally. The pores are situated in well-developed peripodia with a high ridge running transversely adapical to each porepair. A ridge separates the pores of a pair. Each ambulacrum in the holotype has 42 porepairs. The outer pore of each pair is adapical to its partner. Each plate bears a secondary tubercle between the porepair and the medial perradial suture. These tubercles form a double row running down the middle of each ambulacrum.

INTERAMBULACRA.—Each interambulacrum in the holotype is composed of 11 plates, each bearing a large noncrenulate tubercle, except for the first plate at the margin of the apical system in some of the interambulacra. The tubercle is largest on the most dorsal plates where the mamelon is very high, rising 0.6 mm above the parapet. The tubercles decrease in size adorally. The mamelons are all perforate except for those below the margin. In each interambulacral area, 4 or 5 of the tubercles are perforate; 5 or 6 are imperforate. The perforations on the dorsal tubercles are elongated vertically. No scrobicules or scrobicular ring of tubercles are present. The area surrounding each boss is covered with secondary tubercles of equal size. The first plate in the right-hand column of each interambulacrum (as viewed from above) bears the first tubercle (Plate 12: figure 5).

PERISTOME.—The peristome in the holotype has a diameter of 3.6 mm. Slight notches, perhaps gill slits, occur at the edge of the interambulacrum.

LANTERN SUPPORTS.—No apophyses are present. A slight thickening of the plates occurs at the edge of the ambulacra.

COMPARISON WITH OTHER SPECIES.—This species differs from *Zardinechinus lancedelli* (Zardini), also from the St. Cassian beds, in lacking a scrobicular ring of tubercles, and scrobicules, and in having elongated perforations in the mamelons. The adoral tubercles are imperforate in this species, whereas all are perforate in *Z. lancedelli*.

OCCURRENCE.—Misurina, Stolla, St. Cassiano. Collector: Giulini.

Zardinechinus lancedelli (Zardini)

PLATE 1: FIGURES 4, 5; PLATE 13: FIGURE 5; PLATE 14: FIGURES 1–3

Cidaris lancedelli Zardini, 1973:12, pl. 5: fig. 24a,b.
Cidaris admeto.—Zardini, 1973:12, pl. 5: fig. 34a,b, [not Braun in Wissmann and Münster, 1841].
Cidaris cf. *admeto.*—Zardini, 1973:12, pl. 6: fig. 11a,b [not Braun in Wissmann and Münster, 1841].
Zardinechinus lancedelli (Zardini).—Kier, 1977:16, pls. 9, 10, pl. 11: figs. 1–8.

MATERIAL.—MCA 5690, 5716.

In addition, there are three almost complete specimens (private collections, unnumbered) and hundreds of fragments (MCA, unnumbered) that can be referred to this species. The dimensions (in mm) of the three almost complete specimens are given below.

Diam.	*Height*	*No. of amb. plates*	*No. of interamb. plates*	*Diam. of apical system*	*Diam. of peristome*
6.6	3.7	42	11–12	3.3	3.8
8.8	5.1	52	12	–	–
7.2	4.4	48	12	3.2	3.9

OCCURRENCES.—Milieres, Staolin, Campo. Collectors: Zardini, Furlan, Giulini, and Pfaiffer.

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PLATE 1

Unidentified species

1–3. Adoral portion of an ambulacrum showing the auricles produced by the first three plates of each column, MCA 5689, × 14. Campo. Collector: Zardini.

Zardinechinus lancedelli (Zardini)

4, 5. Exterior, interior views of adoral portion of ambulacrum and interambulacrum of MCA 5690, × 16. Note absence of apophyses and presence of auricles. Campo. Collector: Zardini.

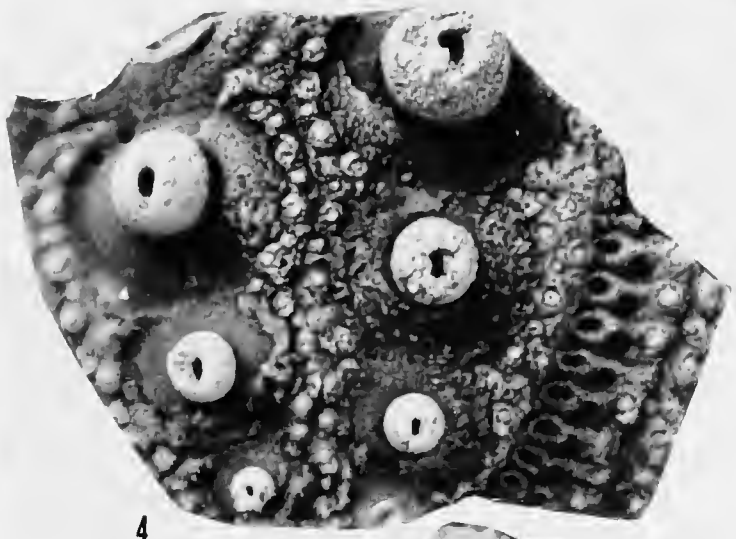
Levicidaris zardinia Kier

6, 7. Exterior, interior views of interambulacrum showing lack of apophyses, MCA 5691, × 12. Misurina. Collector: Zardini.

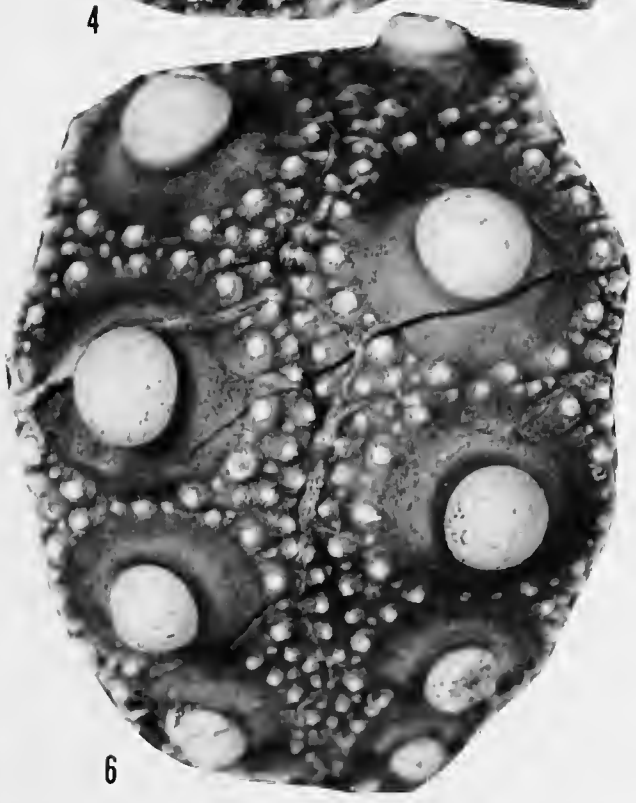

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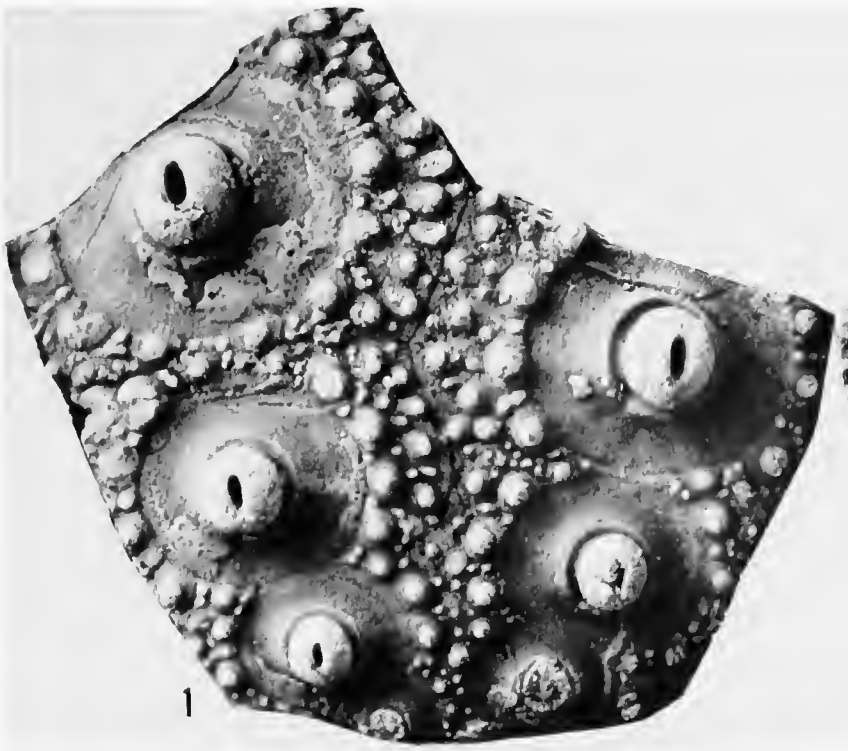
PLATE 2

Species 1

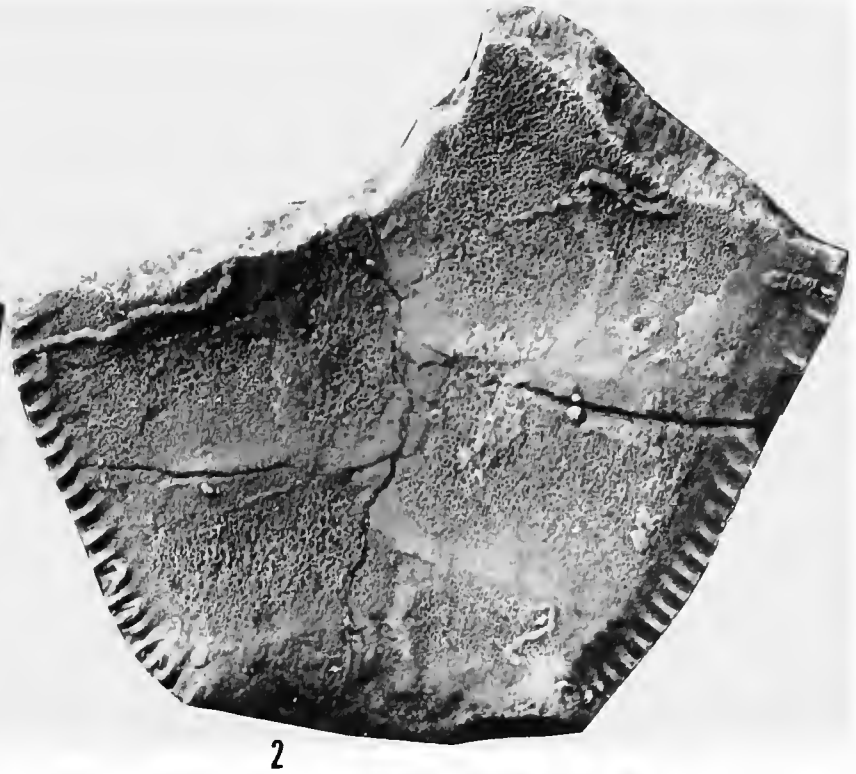
1, 2. Exterior, interior views of MCA 5692 showing absence of apophyses, × 9. Campo. Collector: Zardini.

3, 4. Exterior, interior views of MCA 5693 showing absence of apophyses but presence of protuberance, which was probably the site of insertion of the lantern protractor muscles, × 10. Campo. Collector: Zardini.

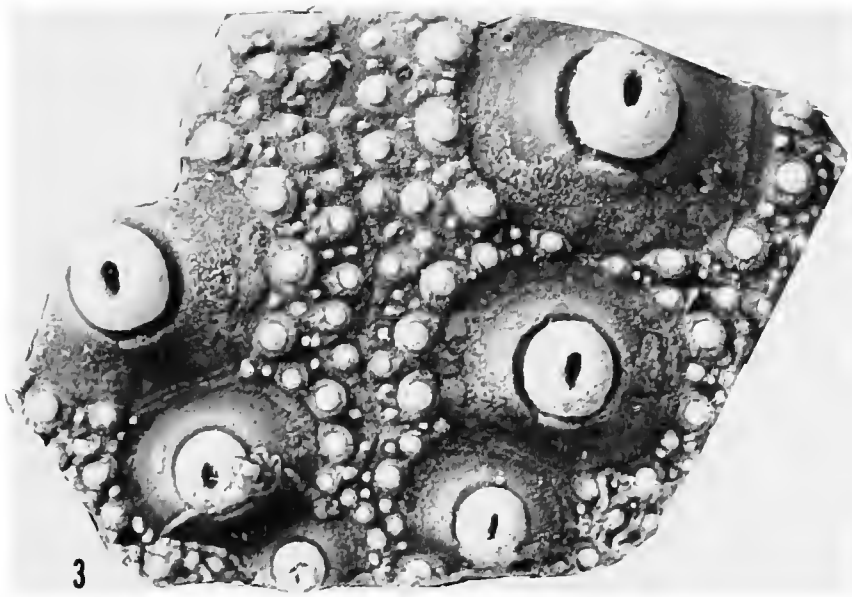
5, 6. Exterior, interior views of MCA 5694 showing absence of apophyses, × 8. Campo. Collector: Zardini.



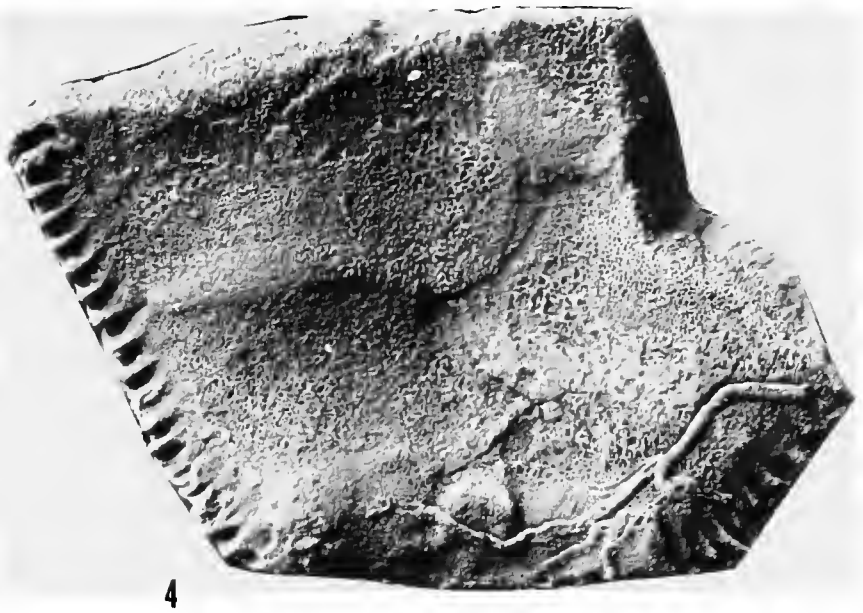
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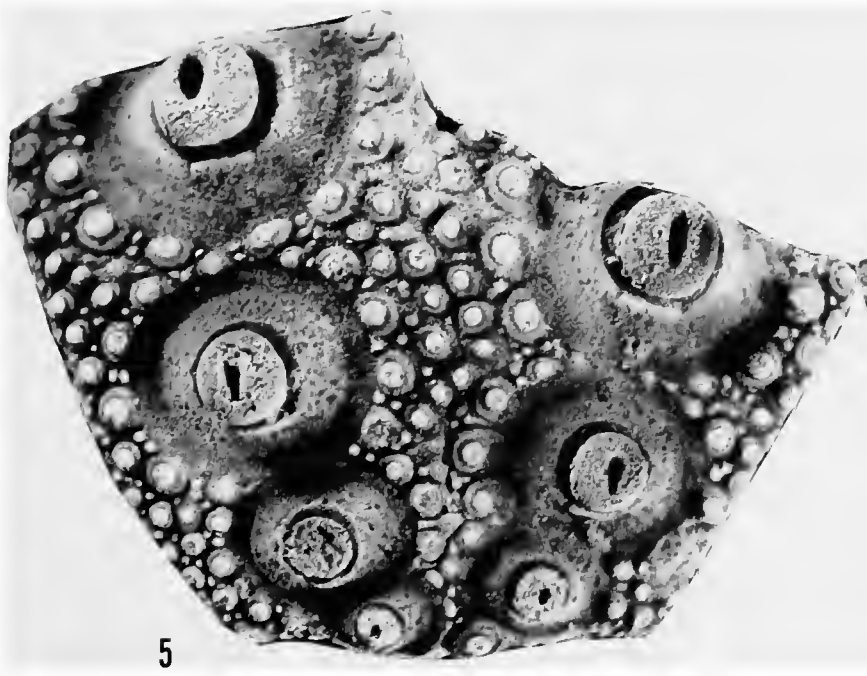
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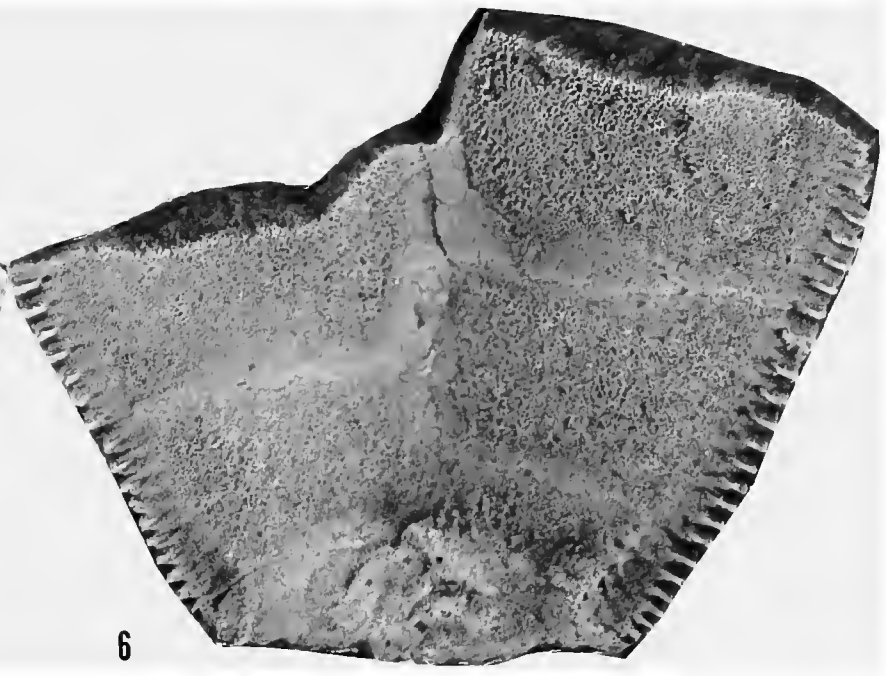
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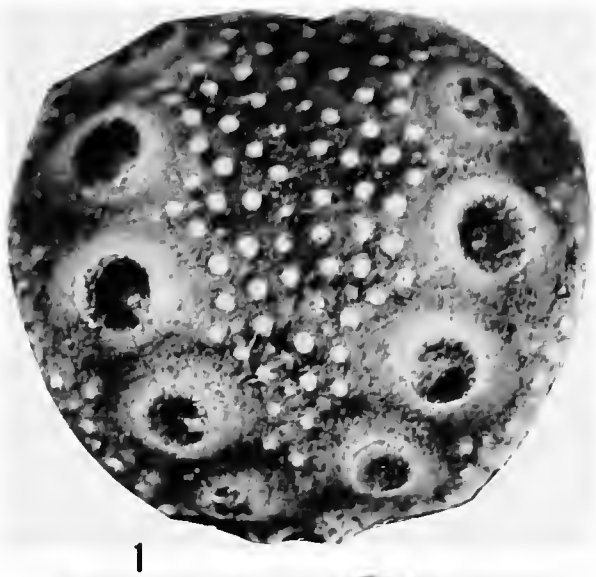


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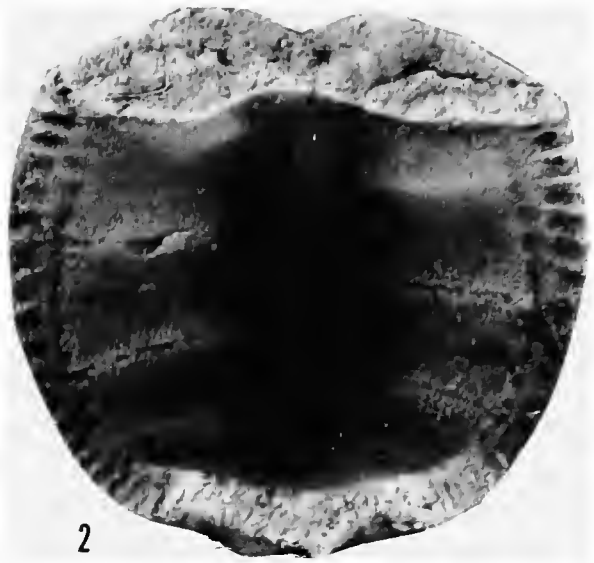
PLATE 3

Species 2

1, 2. Exterior, interior views of MCA 192 showing absence of apophyses, × 14. Cason dei Caai. Collector: Zardini.
3, 4. Exterior, interior views of MCA 5696 showing absence of apophyses, × 16. Campo. Collector: Zardini.
5, 6. Exterior, interior views of MCA 168 showing absence of apophyses, × 12. Rumerlo. Collector: Zardini.



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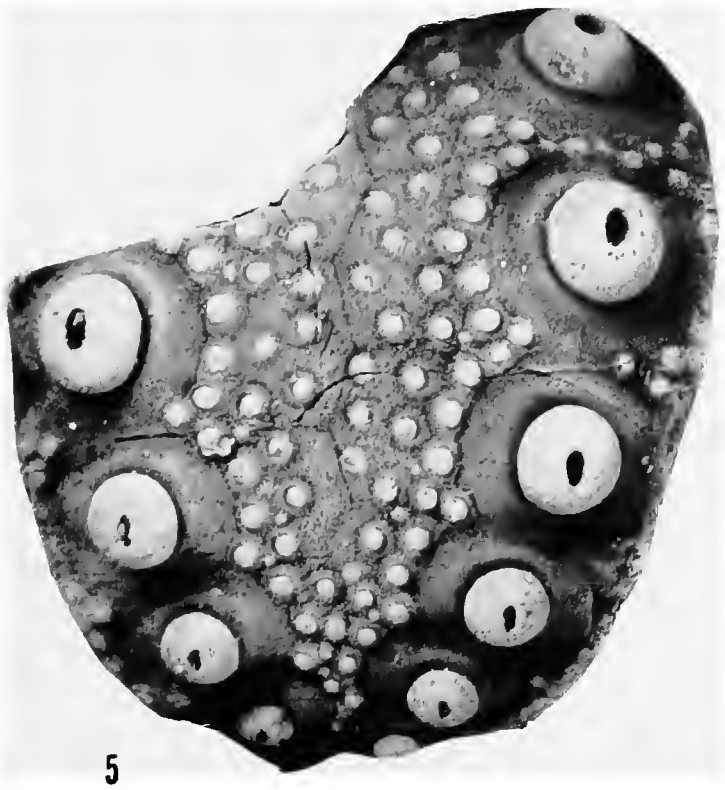
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PLATE 4

Species 2

1, 2. Exterior, interior views of MCA 5698 showing absence of apophyses and presence of a protuberance presumably for attachment of protractor muscles, × 12. Campo. Collector: Zardini.

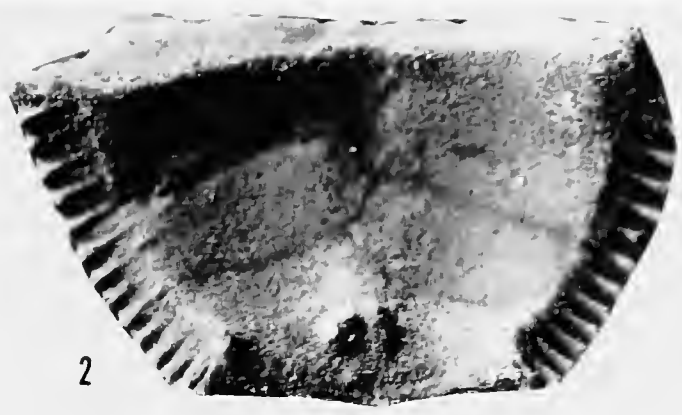
Species 3

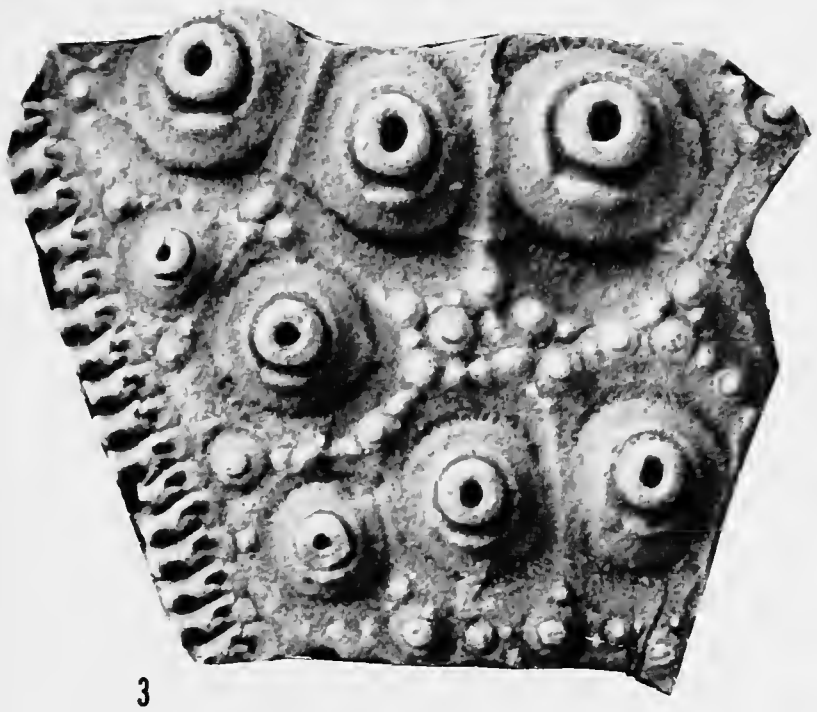
3, 4. Exterior, interior views of MCA 5699 showing absence of apophyses and presence of a large protuberance. Figure 3 (text) shows the location of the plate sutures, × 12. Campo. Collector: Zardini.

"*Miocidaris*" *adrianae* Zardini

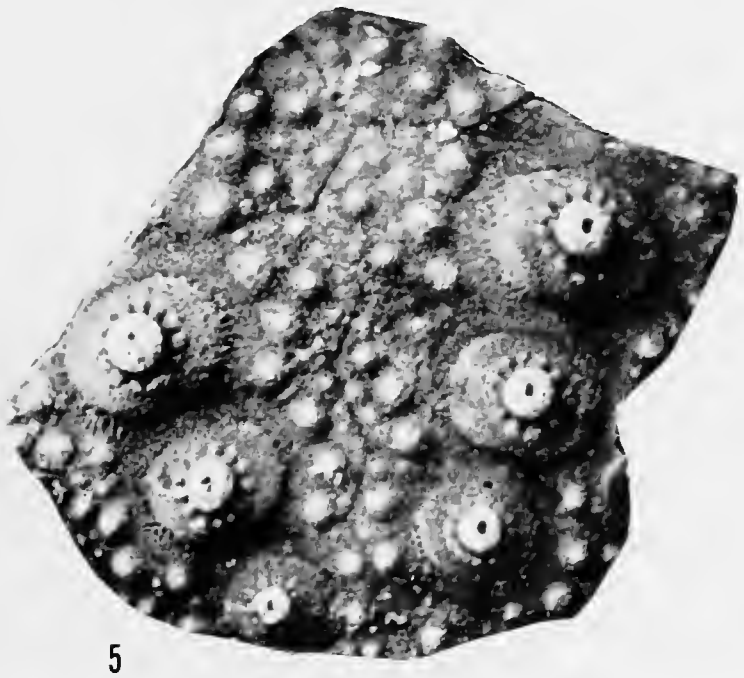
5, 6. Exterior, interior views of MCA 5700 showing absence of apophyses, × 16. Campo. Collector: Zardini.


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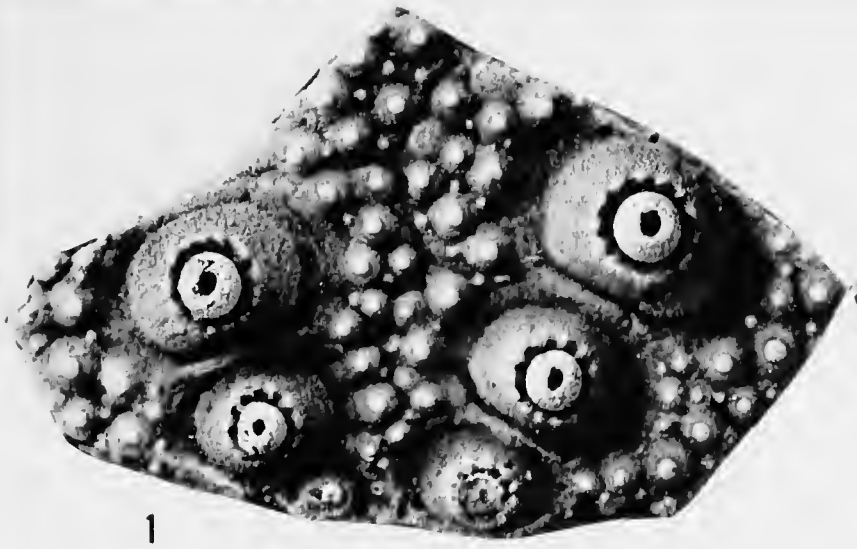
PLATE 5

"Miocidaris" adrianae Zardini

1, 2. Exterior, interior views of MCA 5701 showing absence of apophyses and presence of large protuberance presumably for attachment of protractor muscles, × 9. Campo. Collector: Zardini.

3, 4. Exterior, interior views of MCA 5702 showing absence of apophyses, × 14. Campo. Collector: Zardini.

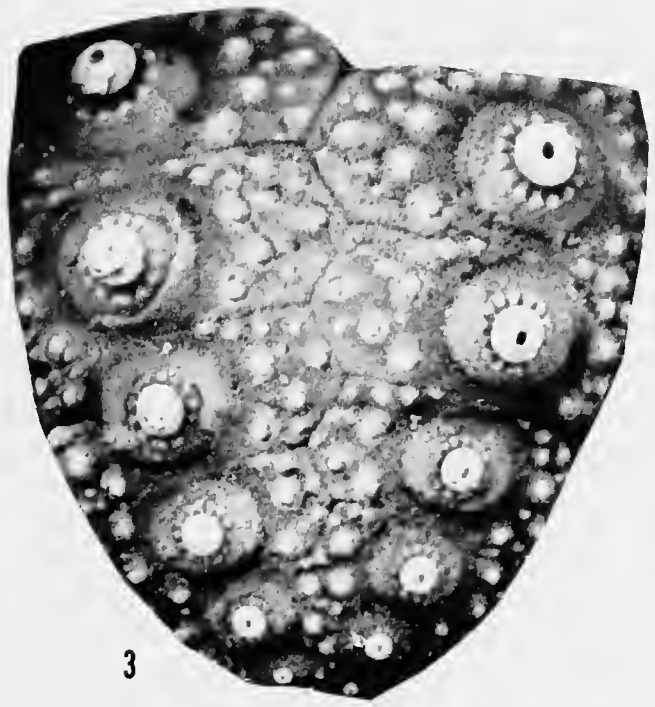
5, 6. Exterior, interior views of MCA 121 showing absence of apophyses and presence of depression on interior opposite the primary tubercle, × 10. Misurina. Collector: Zardini.



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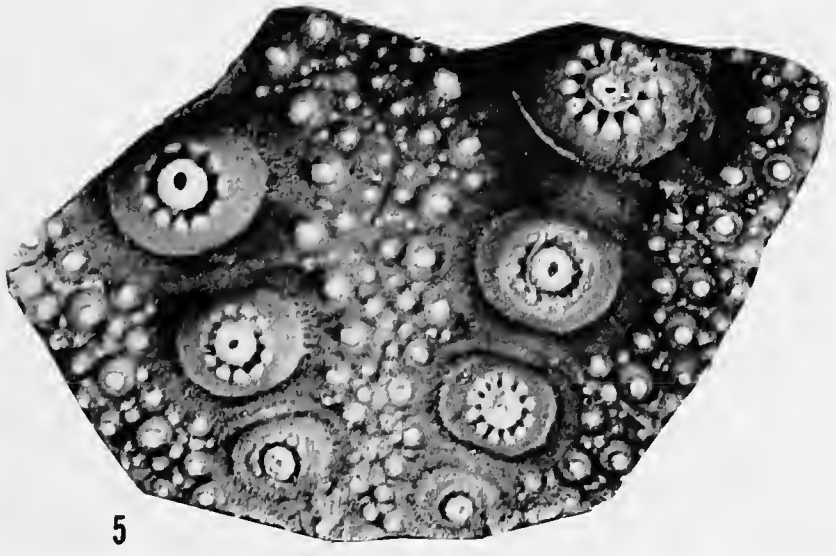
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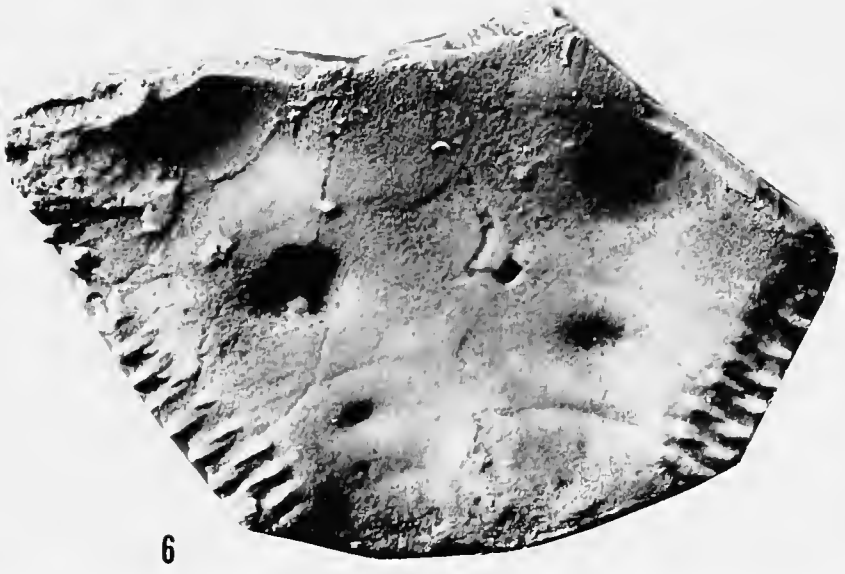
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PLATE 6

Species 5

1, 2. Exterior, interior views of MCA 5704 showing absence of apophyses and presence of a protuberance, × 10. Campo. Collector: Zardini.

Species 6

3, 4. Exterior, interior views of MCA 5705 showing large apophysis, × 9. Misurina. Collector: Zardini.

Species 7

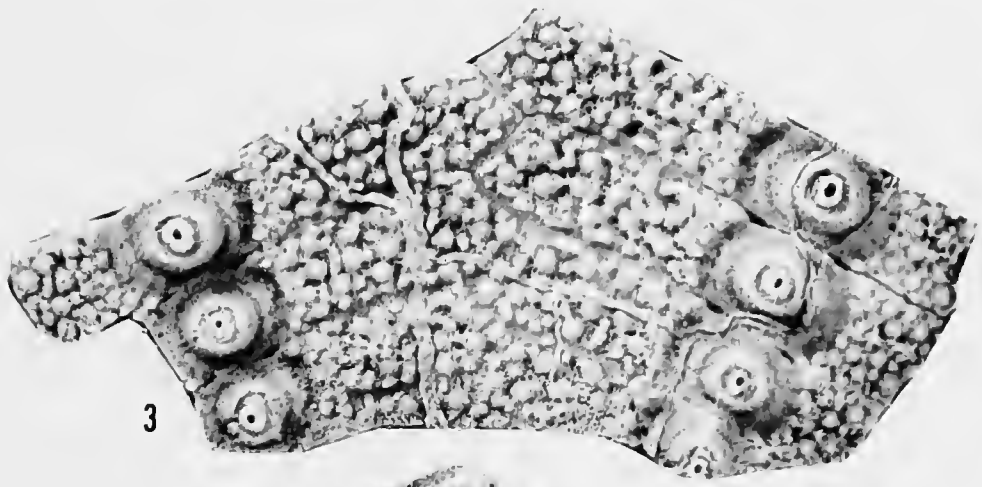
5, 6. Exterior, interior views of MCA 5706 showing large apophysis, × 9. Campo. Collector: Zardini.



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PLATE 7

"Miocidaris" ampezzana Zardini

1, 2. Exterior, interior views of MCA 120 showing large apophyses, × 6. Campo. Collector: Zardini.

Species 8

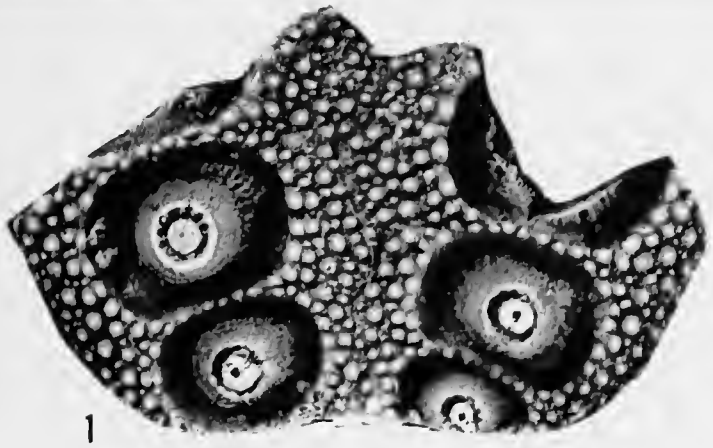
3, 4. Exterior, interior views of MCA 5708 showing large apophyses, × 12. Alpe di Species. Collector: Zardini.

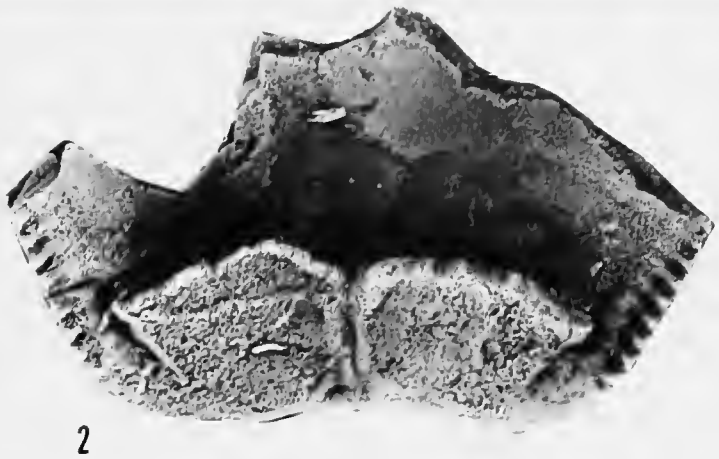
Species 9

5, 6. Exterior, interior views of MCA 5709 showing well-developed apophyses, × 8. Campo. Collector: Zardini.

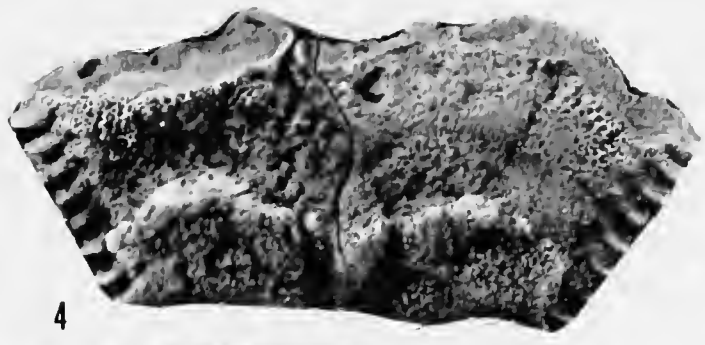
Ambulacra of unknown species

7. Ambulacra composed of primary plates, MCA 5710, × 12. Campo. Collector: Zardini.
8. Ambulacra with a tubercle on alternating plates, MCA 5711, × 16. Misurina. Collector: Zardini.
9. Ambulacra with tubercles covering two plates periodically separated by a plate lacking a tubercle, MCA 5712, × 16. Misurina. Collector: Zardini.

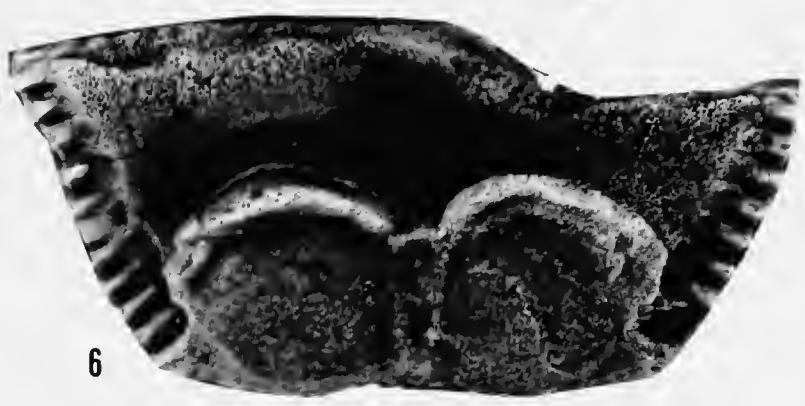

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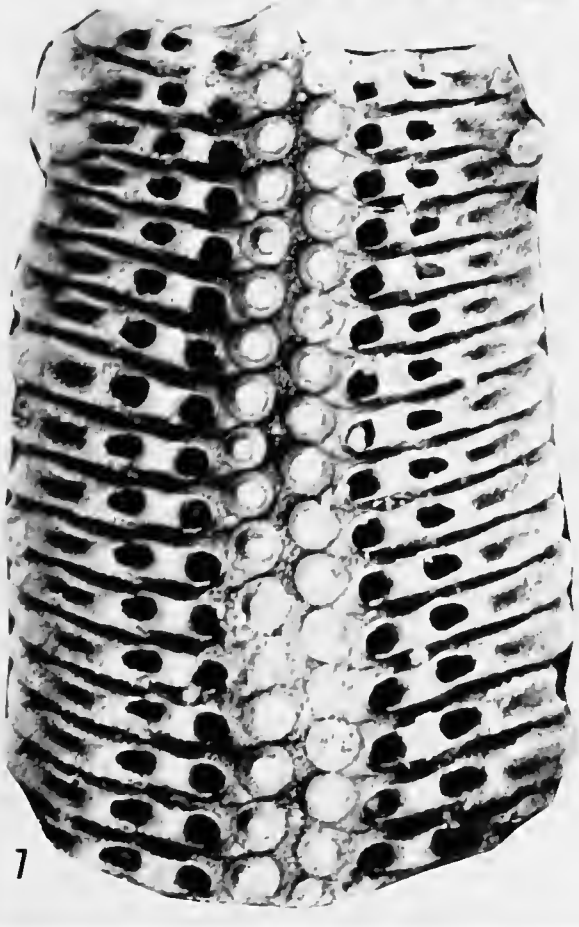

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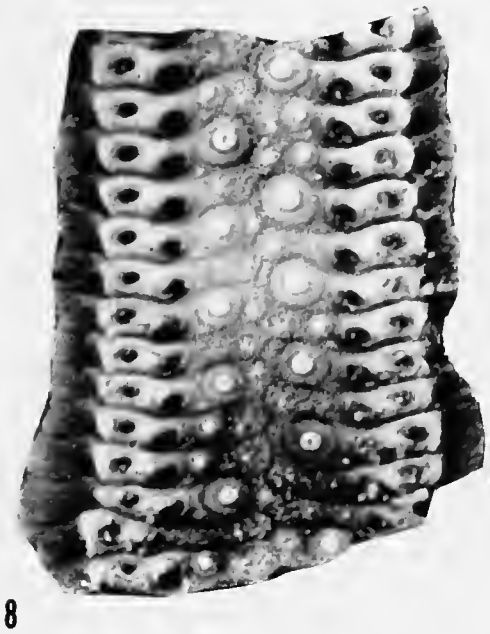

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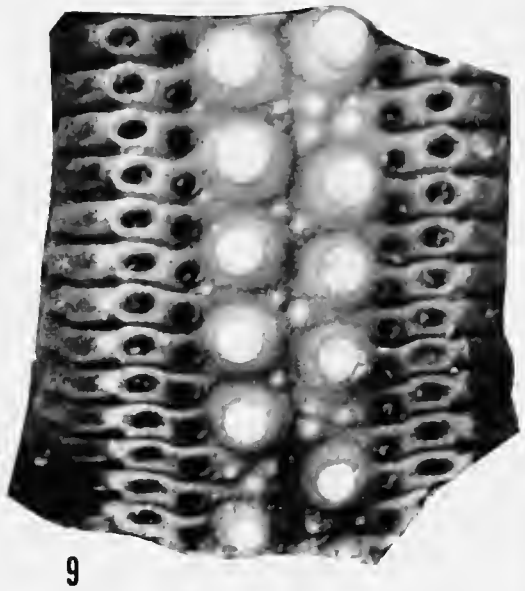

9

PLATE 8

Species ?

1, 2. Exterior and perradial views of a half ambulacrum MCA 5713, showing biserial arrangement of porepairs, × 24. A drawing showing the arrangement of the plates is on Figure 4 (text), Campo. Collector: Zardini.

Mikrocidaris pentagona (Münster)

3, 4. Top, side views of MV 10084, × 18. Milieres. Collector: Giulini.

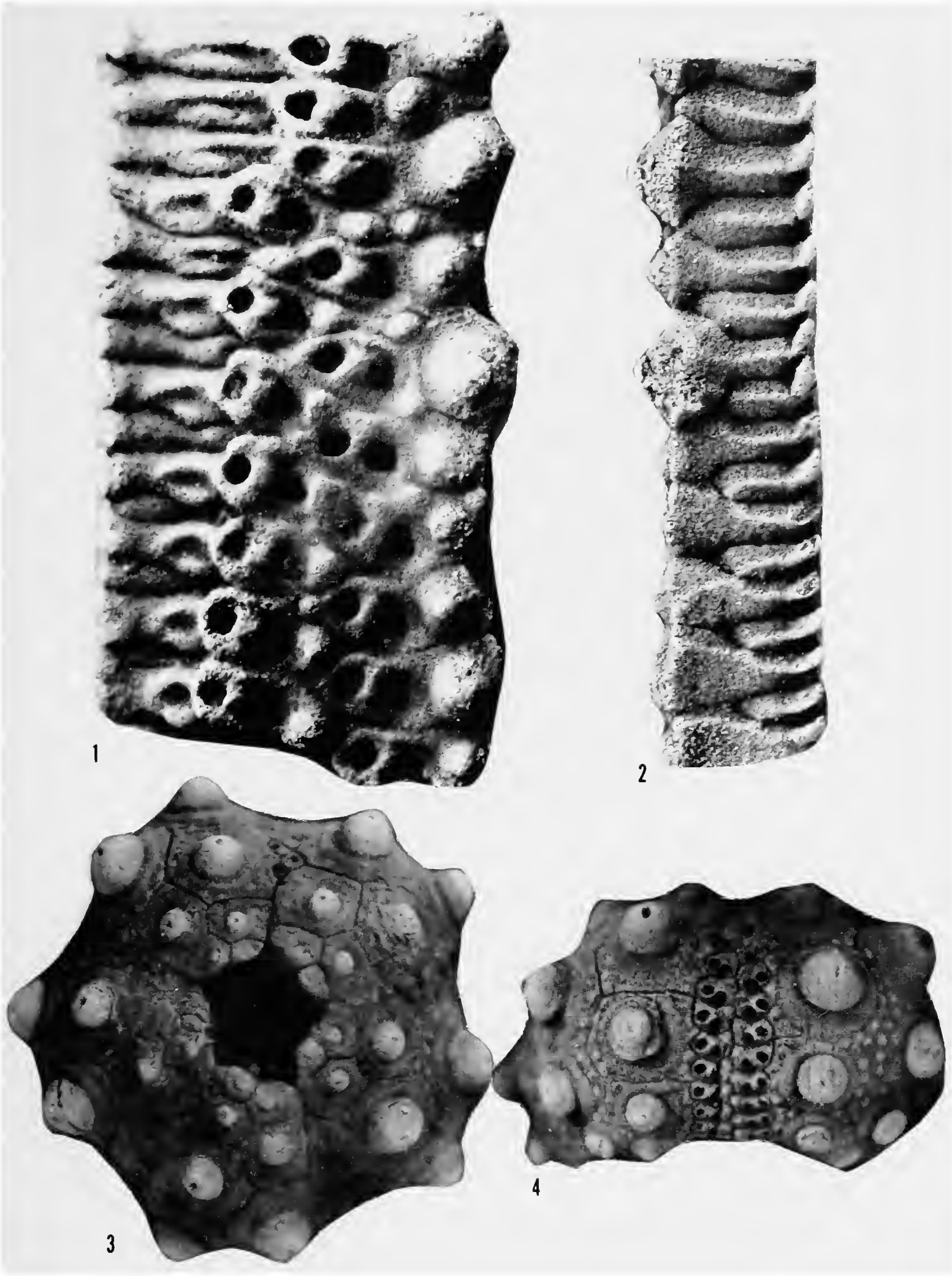
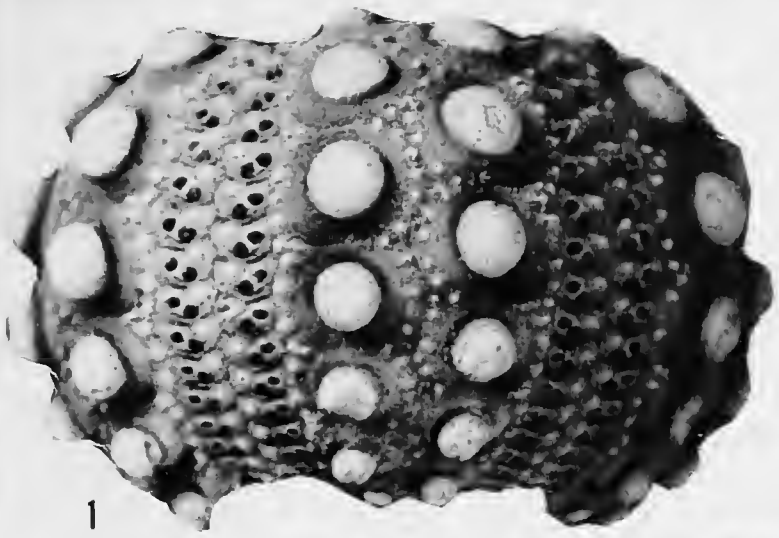

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PLATE 9

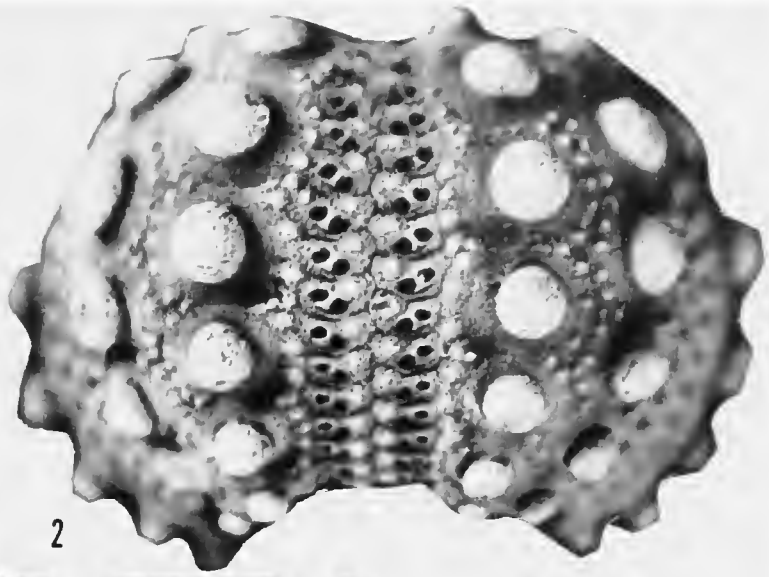
Megaporocidaris mariana Kier

1, 2, 4, 5. Side (1, 2), dorsal (4), and ventral (5) views of MV 10085, × 12. Alpe di Species. Collector: Giulini.

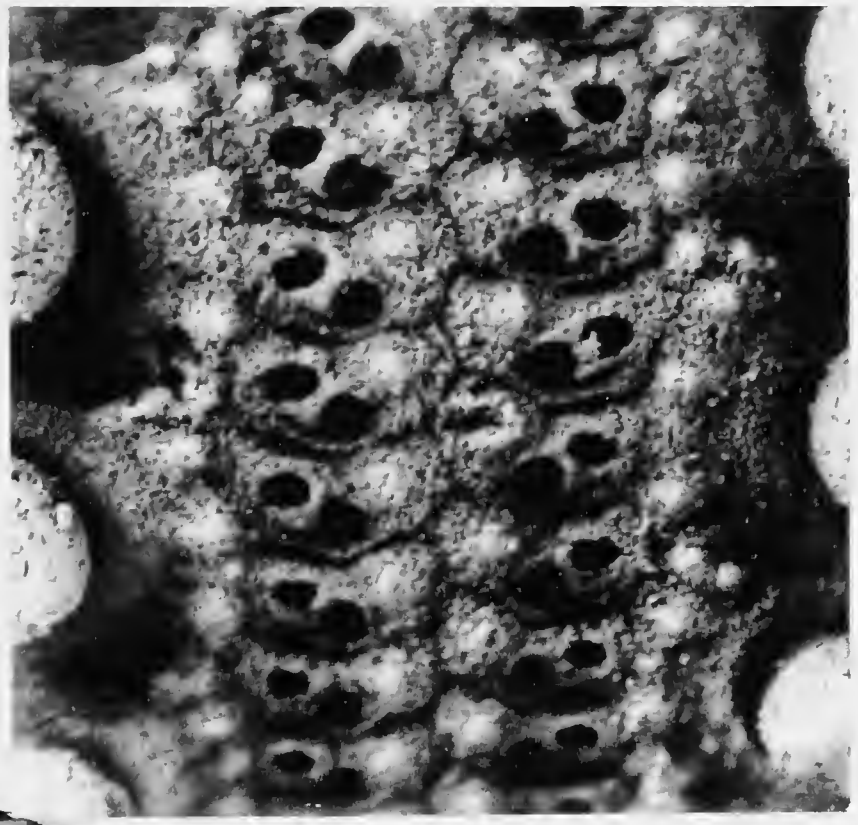
3. Ambulacrum of same specimen, × 36.



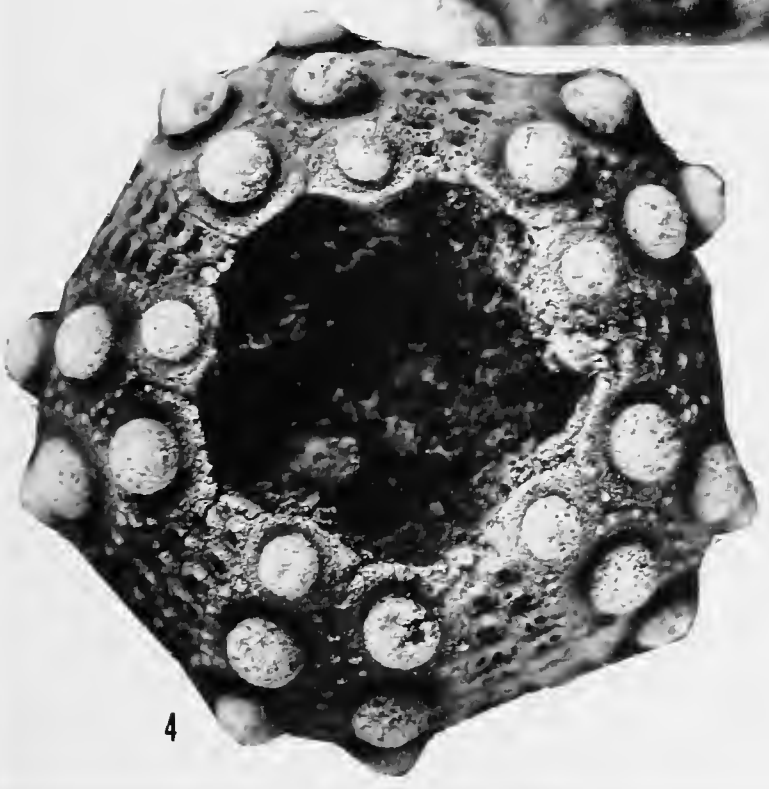
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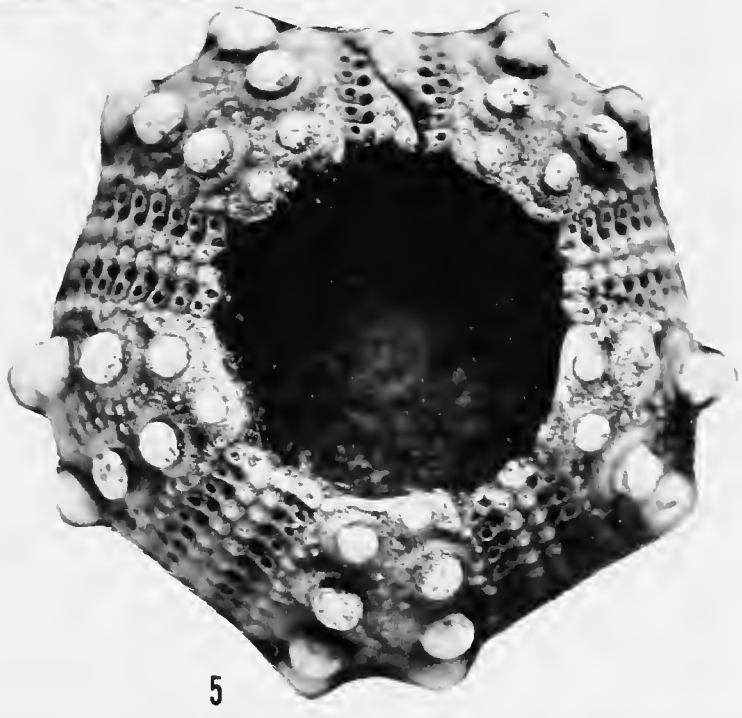
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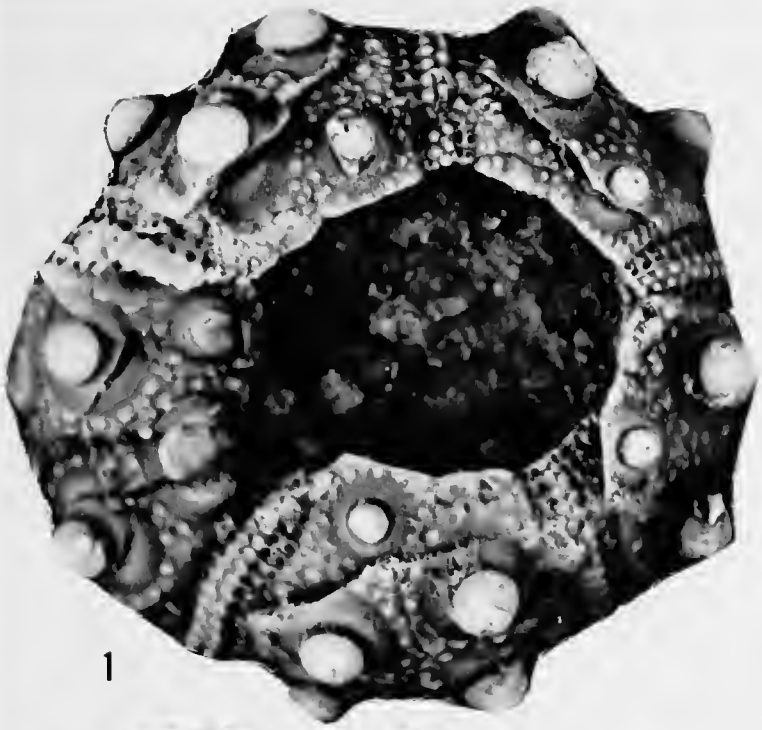
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PLATE 10

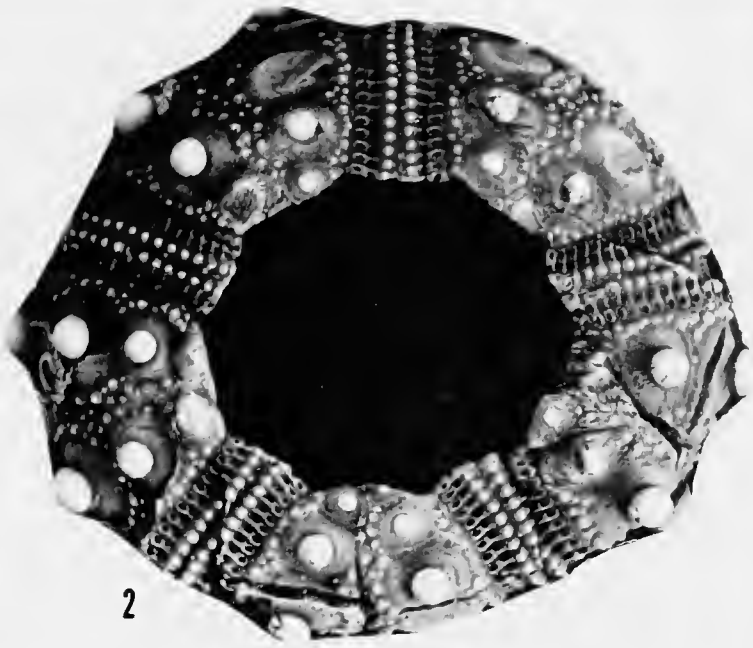
Levicidaris furlani, new species

1–4. Dorsal, ventral, and side views of the holotype MV 10086, × 6. Stolla. Collector: Giulini.

5, 6. Dorsal, ventral views of paratype MCA 5715, × 6. Misurina. Collector: Furlan. Side views of this specimen are on Plate 11: figures 1, 2.



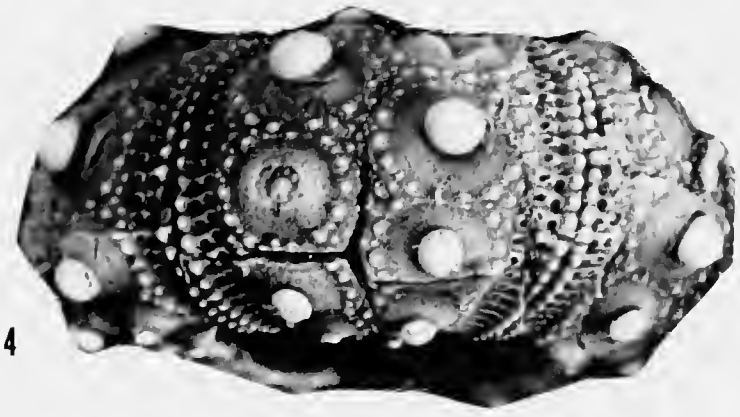
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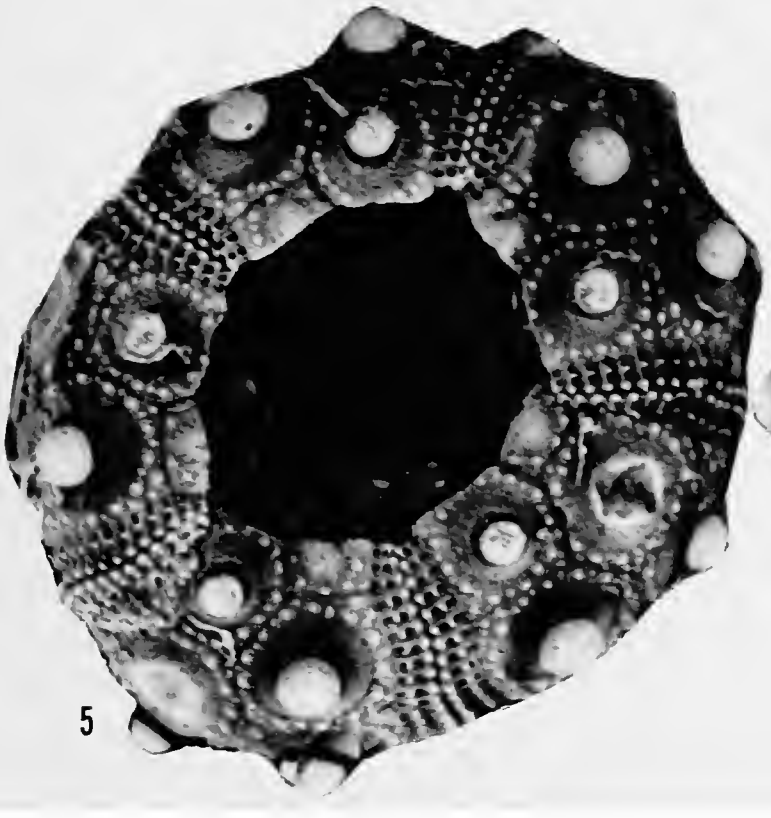
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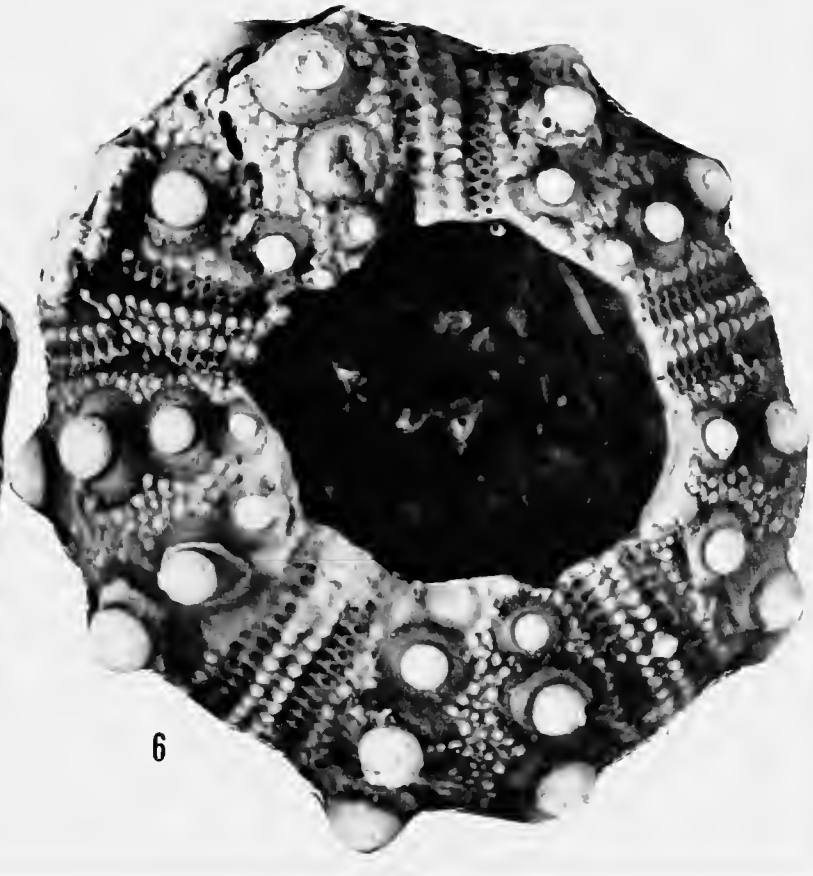
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PLATE 11

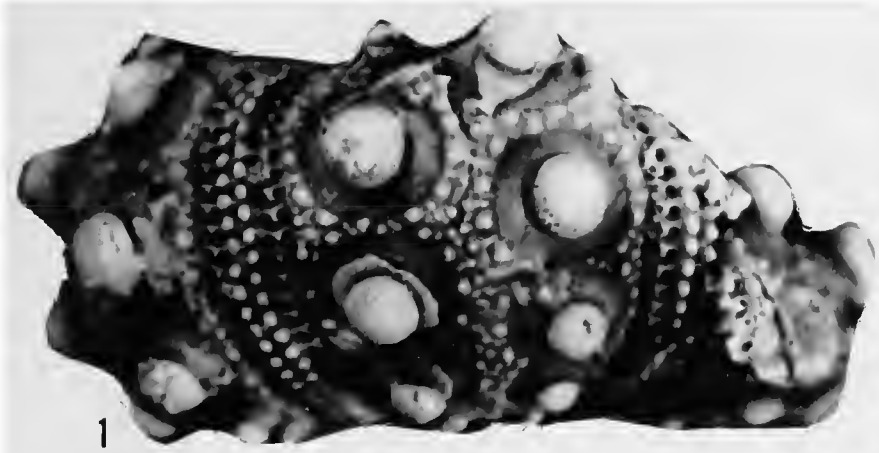
Levicidaris furlani, new species

1, 2. Side views of paratype MCA 5715, × 6. Misurina. Collector: Furlan. Dorsal and ventral views of this specimen are on Plate 10: figures 5, 6.

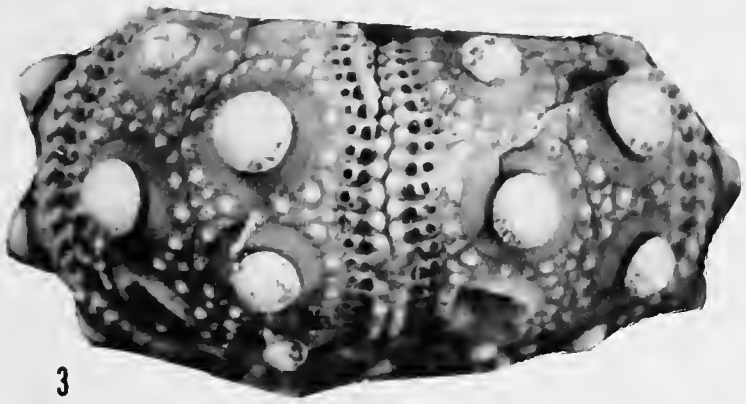
3, 4. Side and dorsal view of paratype MV 10087, × 10. Alpe di Species. Collector: Giulini.

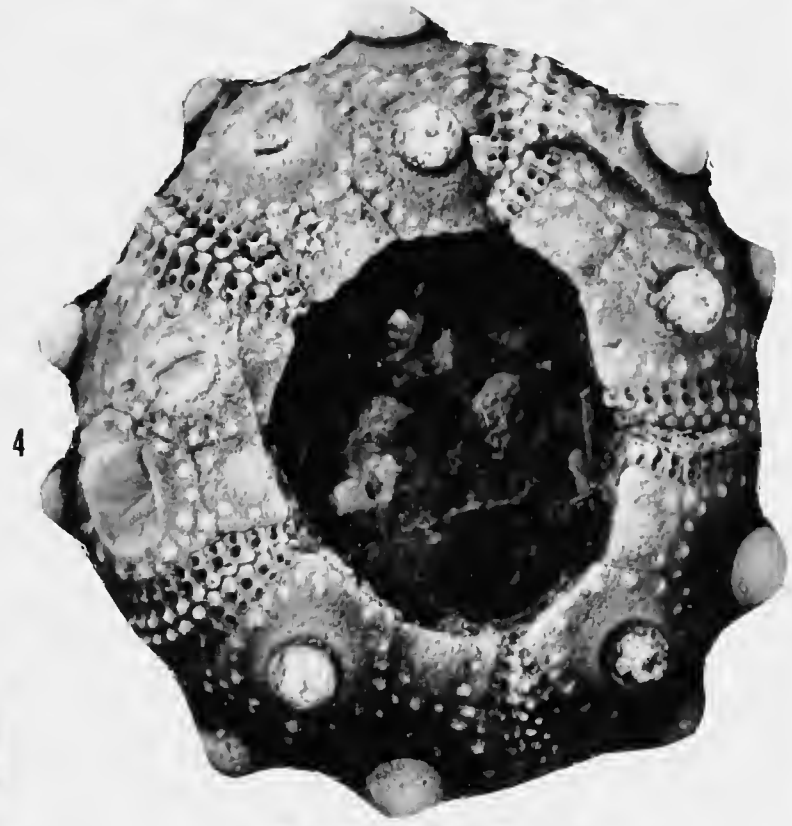
Levicidaris pfaifferi, new species

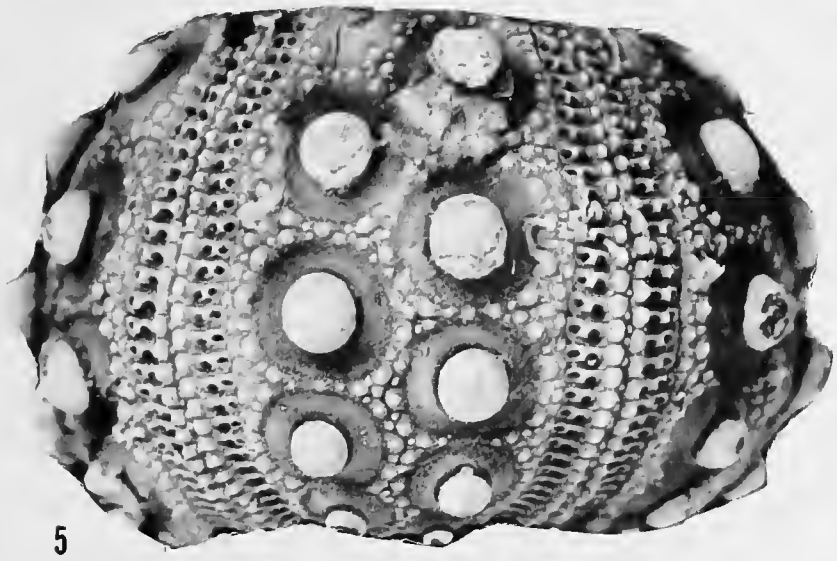
5–7. Side and dorsal views of the holotype (Pfaiffer collection 164), × 7. Misurina. Collector: Pfaiffer. A ventral view of this specimen in on Plate 12: figure 1.

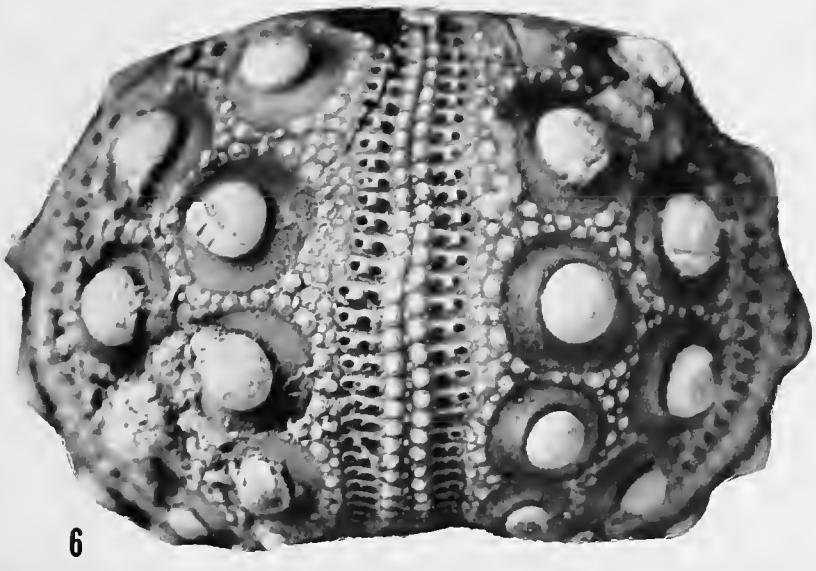

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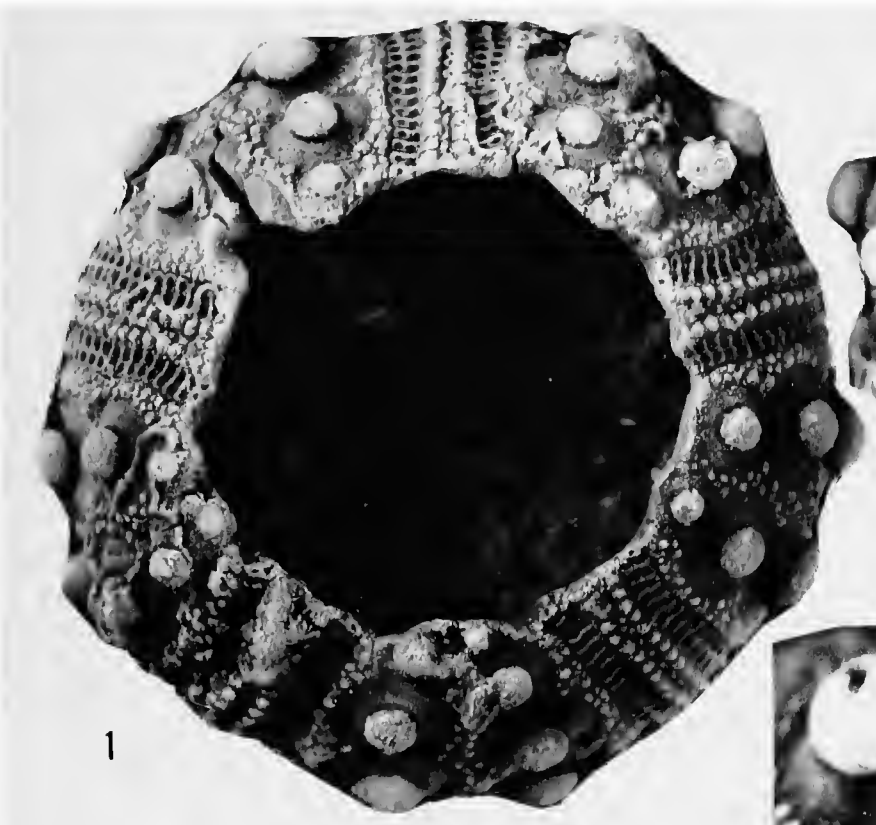
PLATE 12

Levicidaris pfaifferi, new species

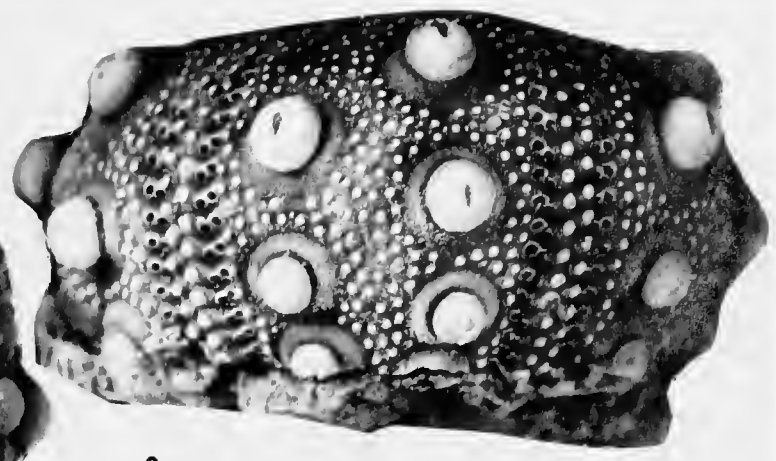
1. Ventral view of holotype (Pfaiffer collection 164), × 7. Misurina. Collector: Pfaiffer.

Zardinechinus giulinii, new species

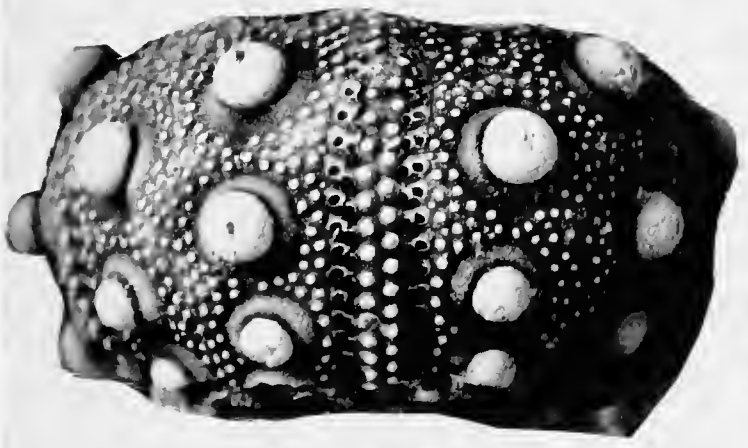
2–4. Side, dorsal views of the holotype MV 10088, × 8. Stolla. Collector: Giulini.
5, 6. Ambulacrum of the same specimen at midzone and adorally, × 16.



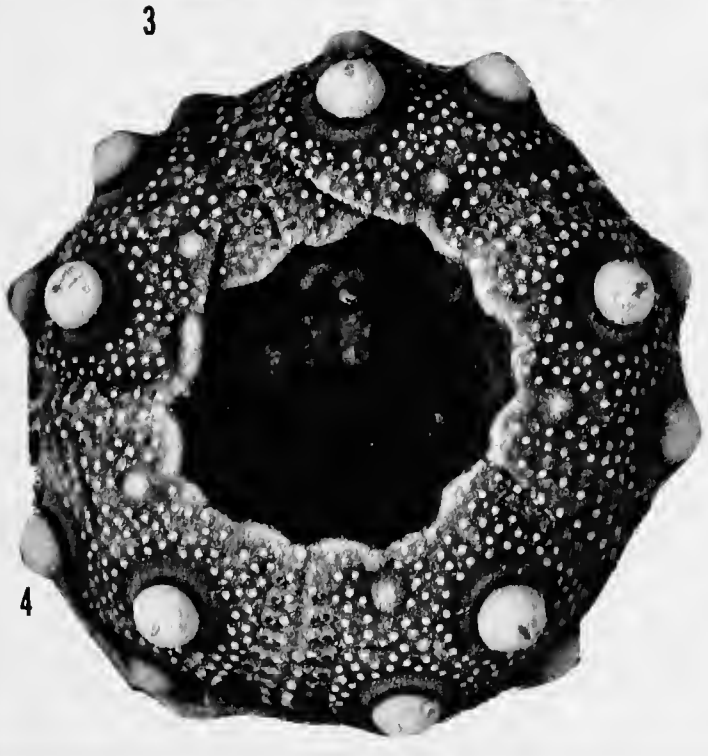
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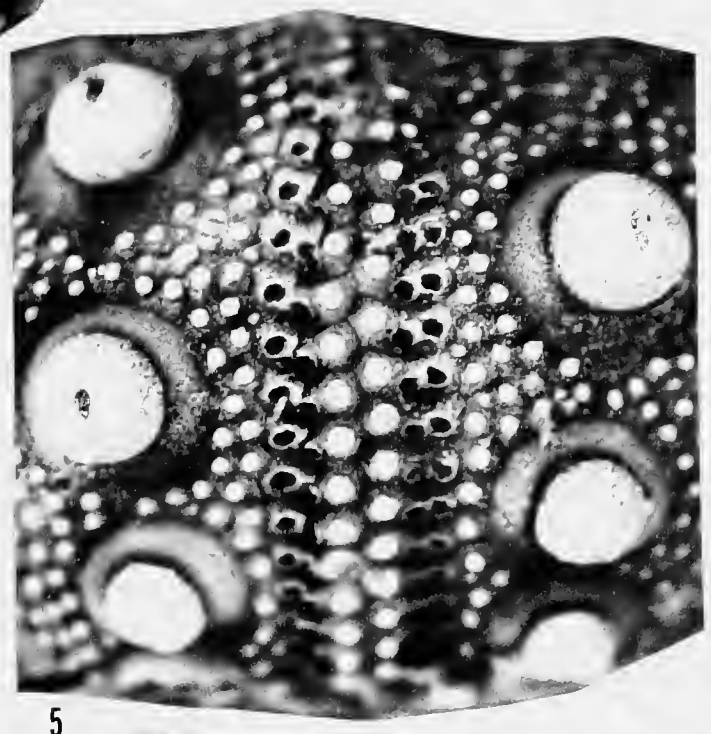
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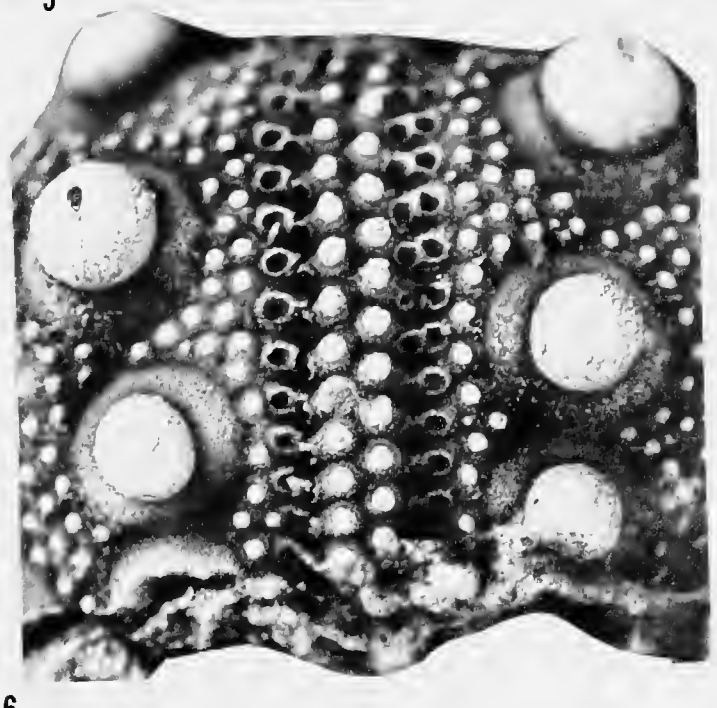
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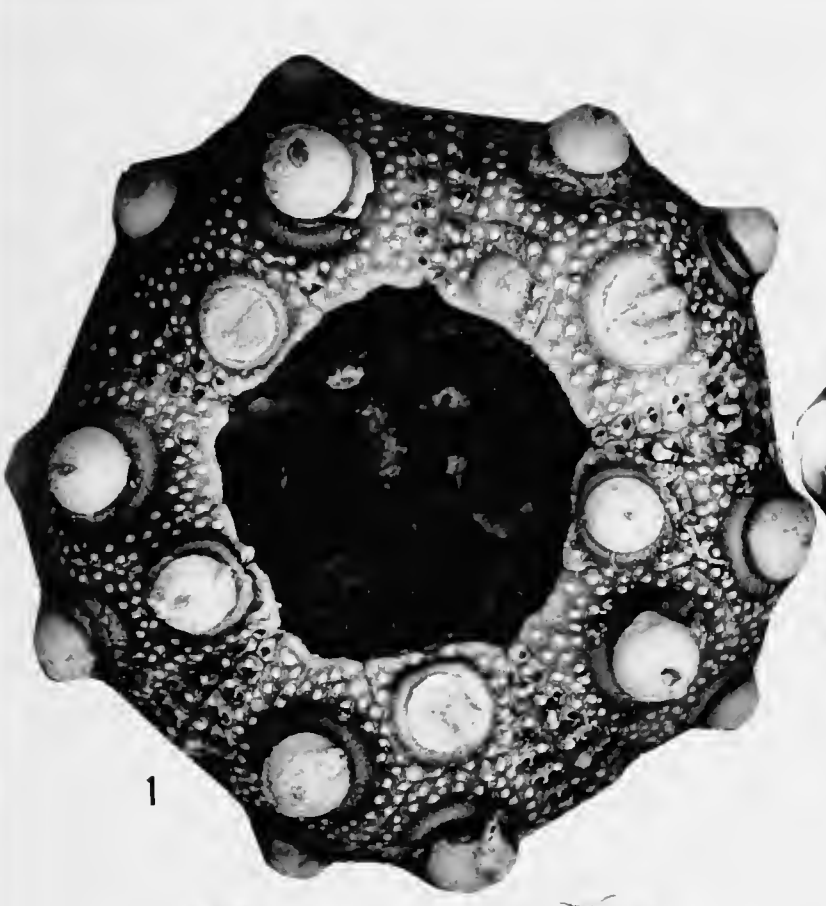
PLATE 13

Zardinechinus giulinii, new species

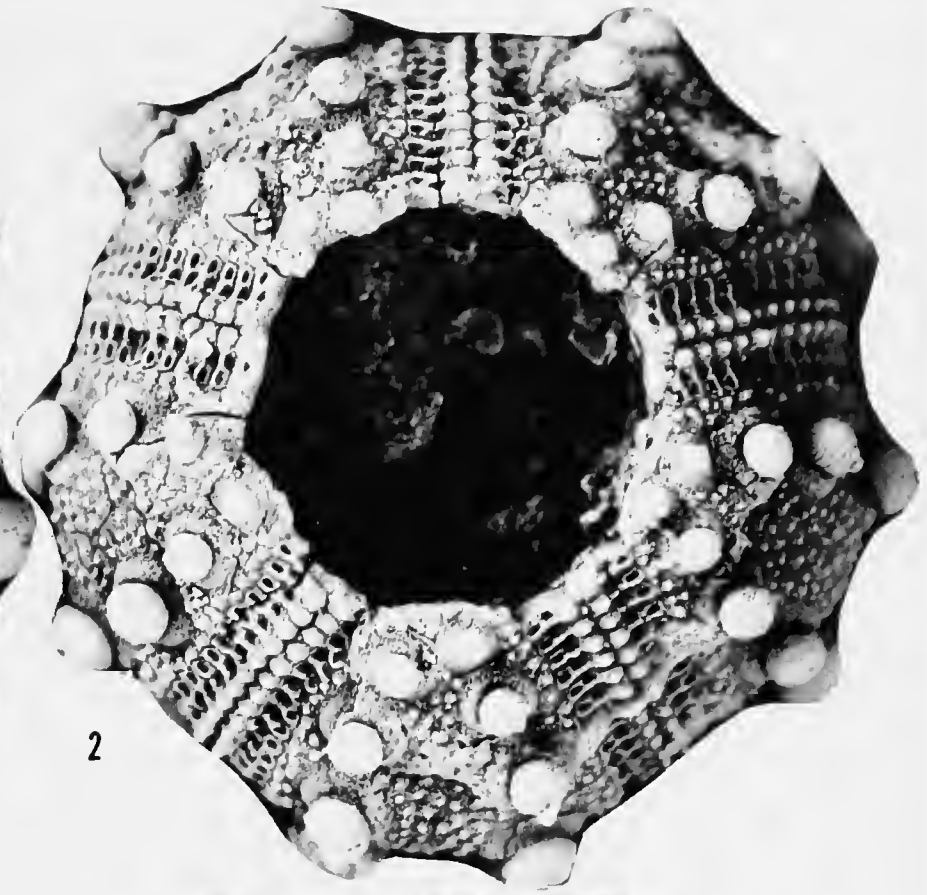
1–4. Dorsal, ventral and side views of paratype MV 10089, × 10. Misurina. Collector: Giulini

Zardinechinus lancedelli (Zardini)

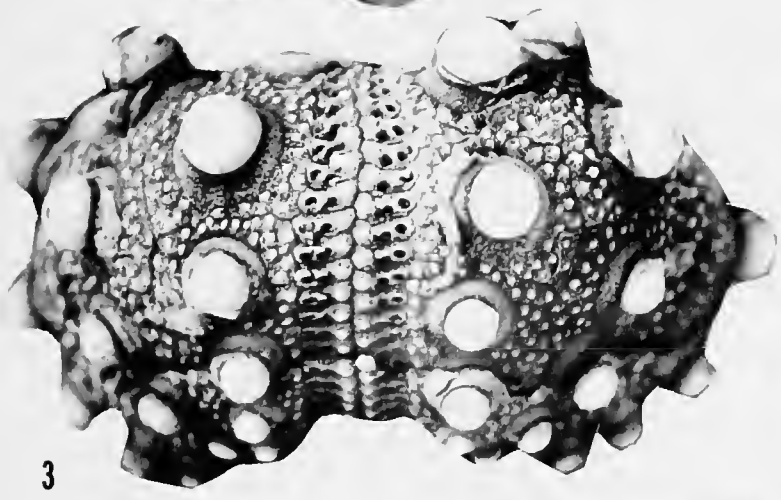
5. Side view of MCA 5716, × 18. Campo. Collector: Zardini. More photographs of this specimen are on Plate 14.



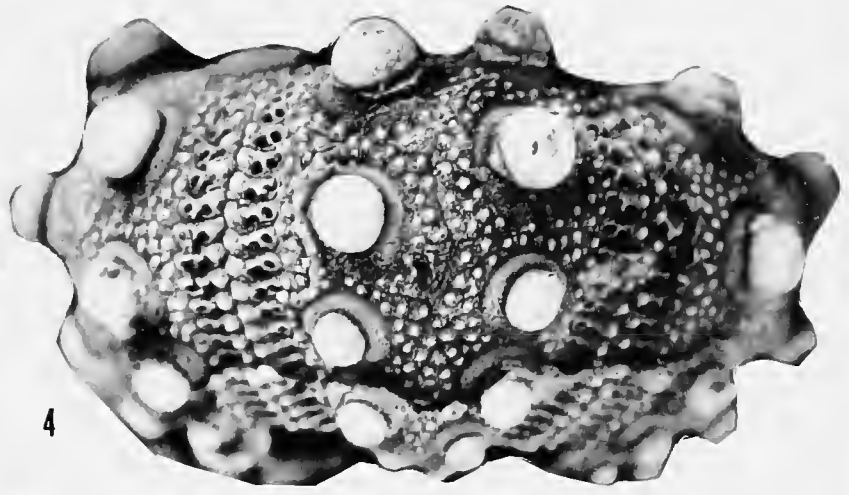
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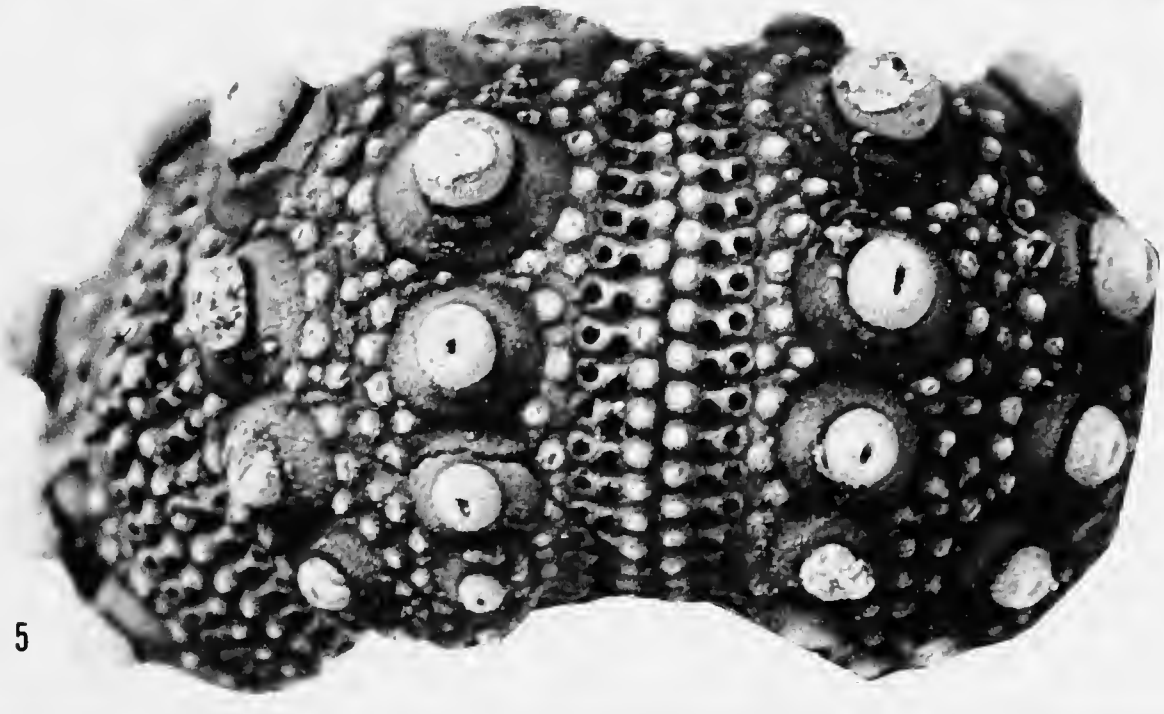
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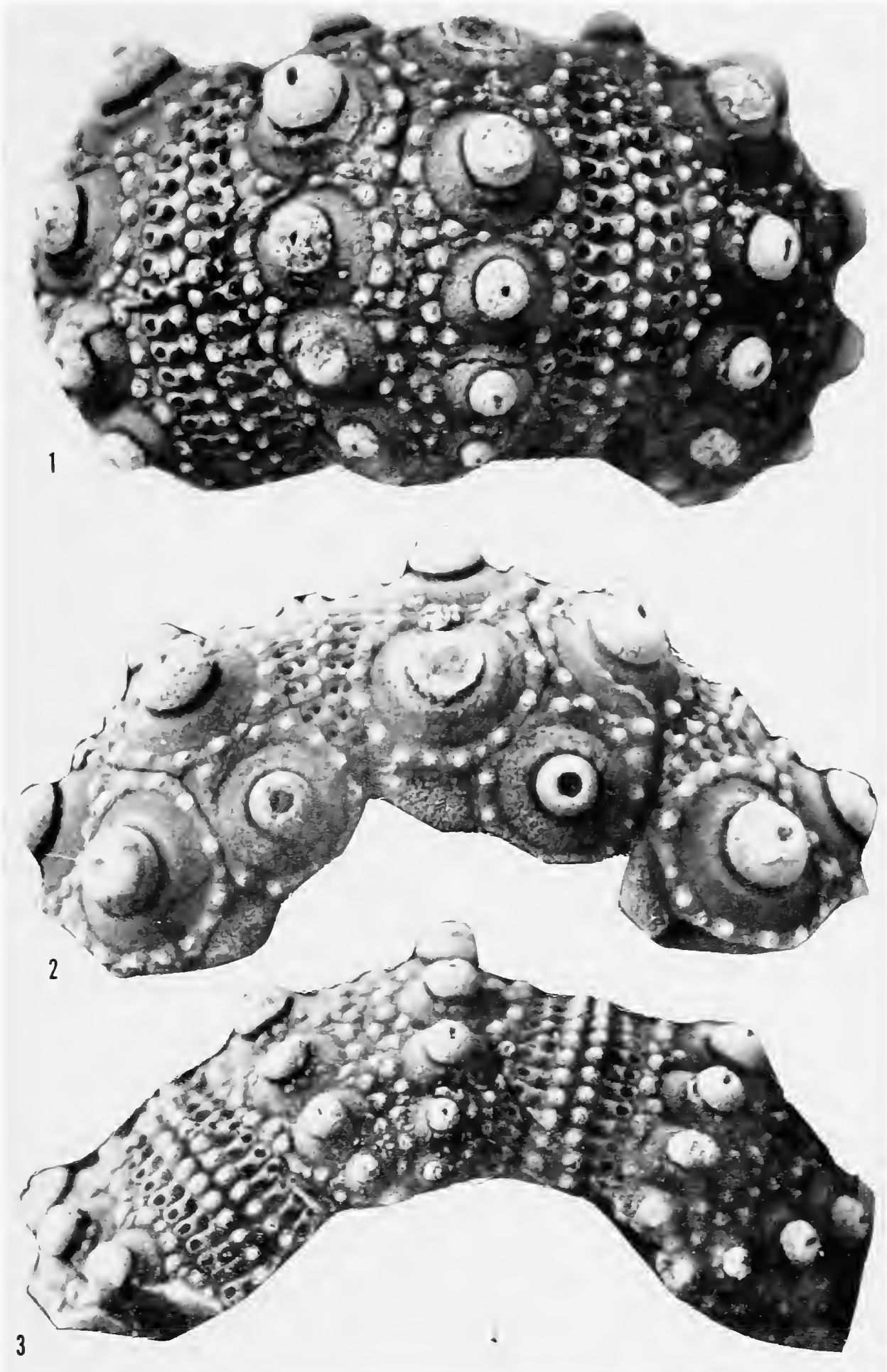


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PLATE 14

Zardinechinus lancedelli (Zardini)

1–3. Side, dorsal, and ventral views of MCA 5716, × 18. Campo. Collector: Zardini.


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REQUIREMENTS FOR SMITHSONIAN SERIES PUBLICATION

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First page of text should carry the title and author at the top of the page; **second page** should have only the author's name and professional mailing address, to be used as an unnumbered footnote on the first page of printed text.

Center heads of whatever level should be typed with initial caps of major words, with extra space above and below the head, but with no other preparation (such as all caps or underline, except for the underline necessary for generic and specific epithets). Run-in paragraph heads should use period/dashes or colons as necessary.

Tabulations within text (lists of data, often in parallel columns) can be typed on the text page where they occur, but they should not contain rules or numbered table captions.

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Taxonomic keys in natural history papers should use the aligned-couplet form for zoology and may use the multi-level indent form for botany. If cross referencing is required between key and text, do not include page references within the key, but number the keyed-out taxa, using the same numbers with their corresponding heads in the text.

Synonymy in zoology must use the short form (taxon, author, year:page), with full reference at the end of the paper under "Literature Cited." For botany, the long form (taxon, author, abbreviated journal or book title, volume, page, year, with no reference in "Literature Cited") is optional.

Text-reference system (author, year:page used within the text, with full citation in "Literature Cited" at the end of the text) must be used in place of bibliographic footnotes in all Contributions Series and is strongly recommended in the Studies Series: "(Jones, 1910:122)" or ". . . Jones (1910:122)." If bibliographic footnotes are required, use the short form (author, brief title, page) with the full citation in the bibliography.

Footnotes, when few in number, whether annotative or bibliographic, should be typed on separate sheets and inserted immediately after the text pages on which the references occur. Extensive notes must be gathered together and placed at the end of the text in a notes section.

Bibliography, depending upon use, is termed "Literature Cited," "References," or "Bibliography." Spell out titles of books, articles, journals, and monographic series. For book and article titles use sentence-style capitalization according to the rules of the language employed (exception: capitalize all major words in English). For journal and series titles, capitalize the initial word and all subsequent words except articles, conjunctions, and prepositions. Transliterate languages that use a non-Roman alphabet according to the Library of Congress system. Underline (for italics) titles of journals and series and titles of books that are not part of a series. Use the parentheses/colon system for volume(number):pagination: "10(2):5–9." For alignment and arrangement of elements, follow the format of recent publications in the series for which the manuscript is intended. Guidelines for preparing bibliography may be secured from Series Section, SI Press.

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Illustrations must be submitted as original art (not copies) accompanying, but separate from, the manuscript. Guidelines for preparing art may be secured from Series Section, SI Press. All types of illustrations (photographs, line drawings, maps, etc.) may be intermixed throughout the printed text. They should be termed **Figures** and should be numbered consecutively as they will appear in the monograph. If several illustrations are treated as components of a single composite figure, they should be designated by lowercase italic letters on the illustration; also, in the legend and in text references the italic letters (underlined in copy) should be used: "Figure 9b." Illustrations that are intended to follow the printed text may be termed **Plates**, and any components should be similarly lettered and referenced: "Plate 9b." Keys to any symbols within an illustration should appear on the art rather than in the legend.

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